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SOVIET SPACE PROGRAMS: 1981-87

SPACE SCIENCE, SPACE APPLICATIONS, MILITARY SPACE PROGRAMS, ADMINISTRATION, RESOURCE BURDEN, AND MASTER LOG OF SPACEFLIGHTS

PREPARED AT THE REQUEST OF

HON. ERNEST F. HOLLINGS, *Chairman*

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

UNITED STATES SENATE

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LETTER OF TRANSMITTAL

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION,
Washington, DC, February 1, 1989.

DEAR COLLEAGUE: Last May, the Committee on Commerce, Science, and Transportation was pleased to release Part 1 of a two-part report on Soviet Space Activities. Today, the Committee is pleased to release Part 2 of this report which deals with the unmanned Soviet space activities and the underlying policy regarding space.

The Committee hopes that this combined report by the Congressional Research Service furthers public knowledge on this issue. The Committee also hopes that this report boadens the base of support for the U.S. space program and helps this Nation recommit itself to maintain leadership in space.

Sincerely,

ERNEST F. HOLLINGS, *Chairman.*

LETTER OF SUBMITTAL

THE LIBRARY OF CONGRESS,
CONGRESSIONAL RESEARCH SERVICE,
Washington, DC, January 30, 1989.

Senator ERNEST F. HOLLINGS,
Senator JOHN C. DANFORTH,
Committee on Commerce, Science, and Transportation,
United States Senate,
Washington, DC.

DEAR SENATORS: In accordance with your request of July 23, 1987, we are herewith transmitting to you Part 2 of *Soviet Space Programs: 1981–1987.* Part 1 was published by your committee last summer. This report completes the update of the *Soviet Space Programs 1976–1980 (with supplementary data through 1983)* series your committee published in three volumes in 1982, 1984 and 1985.

As we agreed, detailed historical information has not been included in this new volume in order to streamline the report. While a historical summary is povided for convenience, the majority of the text focusses only on the years 1984–1987. To the maximum extent possible, we have included information through the end of 1988, the period during which this report was prepared.

Marcia S. Smith, Specialist in Aerospace Policy, Science Policy Research Division at CRS, wrote the text concerning space science activities, and the executive summary. Geoffrey Perry, founder of the Kettering Group in England, wrote the text concerning space applications and military space activities. Peter Daly, Reader in Satellite and Microwave Communications in the Department of Electrical and Electronic Engineering at the University of Leeds, United Kingdom, contributed a special annex on Soviet navigation satellites. Mr. Daly's paper is current through Feb. 10, 1988. Richard Flagg, a U.S. Kettering Group member, prepared an appendix on Soviet lunar exploration. Mr. Flagg's contribution is an abridged version of a paper he wrote while a Research Associate in Radio Astronomy at the University of Florida, and he wishes to thank S. Grahn, G.E. Perry and M. Severance for their discussions and review of the paper. Francis Miko, Specialist in Soviet Affairs, Foreign Affairs and National Defense Division at CRS, wrote the chapter on administration of the Soviet space program under Gorbachev, and John Hardt, Associate Director for Research Coordination and Senior Specialist in Soviet Economics at CRS, wrote the chapter on the resource burden of the Soviet space program. Ms. Smith served as the coordinator for this project.

The report was prepared entirely from unclassified material. Most of the references to written Soviet sources are available in English from the Foreign Broadcast Information Service.

We hope this report will assist you in your continued assessment of Soviet space activities as they relate to the United States space program.

Sincerely yours,

JOSEPH E. ROSS,
Director.

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EXECUTIVE SUMMARY

Since the last edition of this report was published, the Soviet Union has increased its efforts in space science and space applications, learning from Western space programs about the potential profits to be made from the latter. The Soviets also have continued their strong program of military space activities, with evolutionary improvements in several systems.

Under General Secretary Gorbachev, much more information is now available about some aspects of the Soviet space program, notably space science, but the program is far from open by Western standards. The organization of the Soviet government for determining space policy and implementing programs is just as unclear as ever. Although a new space agency was created, its position in the Soviet government and its relationship to other space-related organizations is not well understood. Western observers still have no clear understanding of how much the Soviets spend on space activities. Finally, although the Soviets admit that they conduct military space programs, no information has been forthcoming about them (although this is not surprising and is unlikely to change).

Cooperation and Competition in Space Science and Applications

Since Gorbachev came to power in the Soviet Union, certain aspects of the Soviet space program have become more open. This has been particularly true in space science, where international cooperation has increased dramatically along with greater willingness on the part of Soviet space scientists to discuss future program plans and proposals. This openness has contributed to an impression in the West that the Soviets have taken a leadership position in space science, but that conclusion is premature. In the past, the Western world knew virtually nothing about Soviet plans. Now, Soviet space scientists frequently present papers at international conferences outlining proposals for future planetary exploration, for example. These are just proposals, however. The United States often develops such proposals using advisory groups inside and outside the Government. NASA's Solar System Exploration Committee reports outlining a core program for planetary exploration, the National Commission on Space study providing a 50 year civilian space program agenda, astronaut Sally Ride's report on *Leadership and America's Future in Space,* and the National Academy of Sciences report on *Space Science in the 21st Century* are recent examples of U.S. proposals. Some of these have become approved programs, but many have not. The Soviet proposals also may not become actual programs, or their time lines may lengthen, or their objective may change. Only time will tell.

Western scientists, unaccustomed to hearing Soviet proposals, and concerned about constraints on funding for their own activities, apparently misconstrued the Soviet statements as reflecting approved programs despite repeated Soviet clarifications that they are not. Based on Soviet statements, the only "approved" future planetary exploration program is a 1994 mission to land a spacecraft on Mars, but at the end of 1988, some Soviet scientists were suggesting that even this mission might be postponed.[1] Future Soviet proposals to send spacecraft to Mars in 1996 and 1998 are much more in doubt. Asserting that the Soviet proposals threaten U.S. leadership in planetary exploration, as some Western scientists do, seems based more on emotion than fact. The United States possesses a strong advantage in exploration of the solar system that would not be challenged even if the Soviets completed every program they have suggested. For example, their proposals are for a very limited agenda—exploration of Mars. By contrast, the United States has a broadly based solar system exploration program that in the early to mid 1990s will include probes to Venus, Mars and Jupiter. These are approved, on-going programs, and near-term proposals include additional spacecraft for studying comets and asteroids, and another for investigating Saturn and its moon Titan. U.S. probes have already sent back information from the craters of Mercury to the newly discovered super-heated ocean of Uranus, and all the planetary bodies in between. U.S. leadership in planetary exploration seems secure at least through the end of the century, and a similar case could be made for space physics and astronomy.[2] In fact, three Soviet missions that had been announced as planned for launch in 1988 (Aktivniy for solar-terrestrial physics and Granat and Gamma-1 for astronomy) were not, in fact, launched, demonstrating the uncertainty even of approved Soviet programs.

This does not mean the United States should be complacent if it wishes to maintain leadership in space science, but it is clear that both countries, along with Europe (which has a strong space science program of its own), are seeking areas in which cooperation, not competition, will be the watchword. All space-faring countries are facing the same questions about budgetary allocations. This is certainly one of the reasons that Soviet space scientists are strongly promoting the virtues of international cooperation, which is one method of sharing the burden to permit more expansive scientific programs. Thus, today's focus on arguing the question of "who's ahead" may subside as the superpowers reach agreement on new cooperative ventures.

The field of space applications presents a very different picture, however. There, competition is becoming increasingly important. In space science, competition is primarily for international prestige. In space applications, it is for economic gain. As detailed in Part 1 of this study, the Soviets are trying to market launch vehicle services, albeit unsuccessfully. Commercial marketing is also being pro-

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[1] Soviets May Delay Mars Rover to 1996. Defense Daily, Nov. 30, 1988. p. 150.

[2] Life sciences, another discipline in the space sciences, is discussed in Part 1 of this study: U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Soviet Space Programs 1981-1987: Part 1. Prepared by the Congressional Research Service. Washington, U.S. Govt. Print. Off., 1988.

moted for remote sensing data and communications satellite services. Soviet sales of remote sensing data, in competition with the United States and France, may prove to be the most successful of Soviet commercial space activities, although it remains to be seen whether there is a secure market for Soviet products, or if initial interest is based mostly on curiosity. Soviet communications satellites are very limited in their capabilities, and with an overabundance of capacity on Western satellites, it does not seem likely that the Soviets will succeed in this market niche. The development and international marketing of the Photon satellite for materials processing research underscores Soviet interest both in conducting its own experiments in this field (both on Photon and on their space stations)[3] and in offering unique commercial services. Although only one foreign company has signed a contract to use Photon so far, there is potential growth in this market segment since only the Chinese offer competition for automated orbital flights of materials processing experiments.

In other space applications areas, where marketing has not yet been a driving force, the Soviets have slowly improved existing systems over the past several years. Despite a substantial number of launches related to the new GLONASS navigation satellite system, however, it still is not operational. A new weather satellite, Meteor 3, debuted in 1985, but a second in the series was not launched until 1988 and its success remains uncertain. No dramatic developments in Soviet communications satellite technology occurred during the period being reviewed in this report, although tests of transponders at the 30/20 Gigahertz band, and the use of satellites for relaying communications between ground control and the Mir space station, may presage new systems.[4]

Perhaps the most interesting development in space applications has been the steady program of ocean remote sensing using side-looking radars beginning with Cosmos 1500 in 1983. The satellites in this series have provided considerable assistance to the Soviets in navigating through Arctic ice fields. Cosmos 1870, launched in 1987, also carried a radar for oceanographic studies, and it appears more related to broad remote sensing goals than the specific application of ice navigation. Future plans in this area have not been announced by the Soviets.

Military Space Programs

In 1985, the Soviet Union finally publicly admitted that it conducts military space activities, emphasizing that these are for peaceful purposes such as verification of treaties. The most controversial aspect of military space programs, of course, has been the prospect of weapons in space. No country bases weapons in space today, although both superpowers are performing research on space-based ballistic missile defense weapons. Whether either country will ever deploy such weapons remains to be seen. Gorbachev has publicly stated that his country performs such research, but only in the laboratory phase, and there is no evidence that the So-

[3] Materials processing research on Salyut 7 and Mir is discussed in Part 1 of this study.

[4] The use of the Luch transponder for communications relay between Mir and ground control was discussed in Part 1 of this study.

viets have a coordinated program such as that performed by the U.S. Strategic Defense Initiative (SDI) Organization. SDI is not a space program, but a strategic defense program (that may or may not ultimately involve space-based weapons), and as such is not treated at length in this report. The superpowers are now engaged in arms control talks concerning space weapons, and the fate of the U.S. SDI program and Soviet research in these areas will remain uncertain until the talks are concluded.[5]

Antisatellite weapons, which to date have not involved basing weapons in space, are also controversial. The Soviet Union conducted its last ASAT test in 1982, bringing to 20 the total number of such tests according to Western analysts. The Soviets admit that they tested an ASAT system, but only against points in space, not objects (satellites), in conflict with Western analysis. Continued Soviet misrepresentation of its ASAT activities does not improve the climate for arms control talks in this area, but the question has diminished in importance because of the Soviet hiatus in ASAT testing and the U.S. decision not to proceed with developing an air-launched ASAT of its own (although other ASAT systems are under study).[6] As with the ballistic missile defense systems, the future of ASATs depends at least in part on the arms control talks already underway.

In other military space activities, the Soviets have continued their evolutionary development of new systems for photographic reconnaissance. Fifth generation satellites, which apparently use digital transmission of imagery, were launched beginning in 1984. These new satellites have not replaced the older film-return model, however, nor reduced their frequency of launch. The Soviets now have the ability to monitor the Earth on a continuous basis by launching a large number of the short-lived film-return satellites, with the longer lived fifth generation satellites as a complement. The need to launch as many as 25–30 photographic reconnaissance satellites each year is partially responsible for the high Soviet launch rate which so often leads to the misperception that the Soviets are "ahead" of the United States in space because they launch so often. This high launch rate is primarily indicative of their technological shortcomings that requires them to launch many more satellites to accomplish the same mission objectives as can be met by a handful of U.S. satellites. At the beginning of 1988, U.S. Secretary of the Air Force Edward (Pete) Aldridge stated that the U.S. space program is "far ahead" of the Soviets technologically and qualitatively.[7]

Nevertheless, the high launch rate does give the Soviets an advantage in reconstituting their space assets in times of crisis, assuming that their launch pads are not destroyed in the early part of any conflict. Under peacetime circumstances, however, the need for so many satellites and so many launches must prove to be a

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[5] For a discussion of the U.S. SDI program, see: Moteff, John D. The Strategic Defense Initiative: Program Description and Major Issues. Washington, U.S. Library of Congress. Congressional Research Service, Oct. 25, 1988. CRS Report 88-721 SPR.

[6] For a discussion of U.S. ASAT activities, see: Smith, Marcia S. ASATs: Antisatellite Weapon Systems. Washington, U.S. Library of Congress. Congressional Research Service, 1988. Issue Brief 85176. Updated regularly.

[7] USA "Leads in Space." Flight International, Jan. 30, 1988. p. 17.

drain on Soviet resources. Although some Western observers postulate that with the addition of two new launch vehicles (see Part 1 of this study) the Soviets will launch more and more satellites, it is equally possible that with better technology, they will launch fewer and fewer, as did the United States.

One Soviet military space program that received considerable attention in 1983 and 1988 is the nuclear reactor powered RORSAT (radar ocean reconnaissance satellite) series. The malfunction of Cosmos 1402 in late 1982 caused the satellite to reenter over the Indian and Atlantic Oceans in early 1983. Usually when a RORSAT's mission is completed, the nuclear reactor portion of the satellite is boosted into a very high orbit from which it will not decay for hundreds of years and the radioactivity has subsided. This mechanism failed on Cosmos 1402, as it had on Cosmos 954 which spread radioactive debris over northern Canada in 1978. This time the debris fell over ocean areas and the incident demonstrated a technique apparently adopted after Cosmos 954 to eject the reactor's core (the most radioactive part of the spacecraft) to ensure that it would vaporize during reentry. In 1988, yet another RORSAT, Cosmos 1900, suffered problems that threatened to result in radioactive material reentering Earth's atmosphere. In this case, fail-safe sensors on the satellite were able to trigger the boost to higher orbit even though the Soviets had lost communications with the spacecraft. This again apparently showed the Soviet ability to modify RORSATs to reduce the hazard from space nuclear power sources.[8]

The success of the fail-safe systems probably will add to Soviet confidence about these nuclear powered satellites, but an international movement to sharply restrict the use of nuclear reactors in Earth orbit may create problems for the Soviets in this regard (they are the only ones who currently use reactors in space, although the United States uses another type of nuclear power source for some planetary spacecraft). The Committee of Soviet Scientists Against the Nuclear Threat, headed by Dr. Roald Sagdeyev (Director of the Soviet Institute for Space Research at the time) issued a press release jointly with the U.S. Federation of American Scientists in 1988 specifically calling for termination of the RORSAT program and recommending constraints on other nuclear power sources for spacecraft. Although the Soviet government does not seem to have adopted this resolution, it does underscore the growing concern about Soviet RORSATs from a safety perspective.

Determining future Soviet intentions with regard to military space activities is impossible from open source literature (and is probably extremely difficult even from classified sources). It is too simplistic to assume that their program development would parallel that of the United States. Thus, attempting to forecast future military space intentions is a fruitless task, other than to assume that existing systems will evolve as funding and technology permit.

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[8] The word "apparently" is used because the Soviets have not stated when the core ejection system demonstrated on Cosmos 1402 or the fail safe systems on Cosmos 1900 were installed. It is possible they were on earlier satellites, like Cosmos 954, and failed, but it seems more likely that they were successively added to the RORSATs as a result of the Cosmos 954 and Cosmos 1402 failures.

Soviet Space Organization and Funding

Unfortunately, the greater Soviet openness about their space program has not improved Western understanding of how the Soviet government is organized for space policy decision making and program implementation. The creation of a new space agency, Glavkosmos, seems to have added another spoke to the wheel rather than consolidating authority. Where Glavkosmos fits in with other groups such as the Soviet Academy of Sciences and the Ministry of Defense, both of which are thought to play major roles in space policy and program decisions for civilian and military activities respectively, is not known.

Nor have the Soviets yet revealed how much they spend on their space program. Unless they publicly reveal such information, it will be almost impossible to determine whether Gorbachev has increased or decreased attention to space, since space programs have gestation periods of a decade or more and the results would not be seen for quite some time. More openness on the part of the Soviets, as well as U.S. intelligence agencies who make their own estimates of funding, would be required for useful measurements of Soviet spending. Until then, the conventional wisdom, or "rule of thumb," that the Soviets spend approximately one and a half times as much as the United States will have to suffice.

What changes to the space program might result from the emergence of Gorbachev's perestroika remains a matter of great conjecture. It is clear that military programs per se will not be exempt from Gorbachev's review of targets for reduced spending, but existing military space programs for verification and other reconnaissance, communications, and the military/civilian navigation and weather satellite programs will probably be safe from the budgetary axe. Whether civilian space programs like space science and the use of crews in orbit, and new military space programs, will enjoy any protection is less certain. The recent emphasis on commercial profits to be gained from some space activities, and on international cooperation in space science, may be the first clear signal that budget pressures have begun to impact the civilian program. Glavkosmos, the new Soviet space agency, has been directed to become "self-financing," and now will charge foreign cosmonauts $10 million to visit the space station Mir (previously this was done for free in the interests of international cooperation and prestige). Greater emphasis also may be placed on "spinning off" technologies from military space programs to civilian activities (including, but not limited to civilian space).

Conclusion

It is too soon to tell what changes may result in Soviet space activities from Gorbachev's perestroika. To Western observers, the most obvious, and welcome, change is increased access to information about the Soviet space program. One could only hope for more. Certain parts of the program, particularly those for military support, seem likely to continue to be wrapped in security (as are U.S. military space programs), but strides could be made in clarifying the Soviet space policy and program implementation apparatus,

quantifying Soviet space spending, and detailing future space applications programs.

One of the most interesting facets of the Soviet space applications programs will be watching the success or failure of commercialization efforts. There is potential in both sales of remote sensing data and materials processing flight opportunities on Photon spacecraft. How vigorously the Soviets pursue these areas, and what compromises they are willing to make (such as allowing foreign visitors at previously closed launch sites in order to attract customers for launch services) in order to succeed, may provide new clues as the future direction of the Soviet space program.

SECTION ONE: AUTOMATED SPACE PROGRAMS

CHAPTER 1—HISTORICAL OVERVIEW 1957–1983

Previous editions of this report have been self-contained, with each new version repeating all the historical information from past editions. For this report, however, only new material is presented in detail. This historical overview covering the years 1957–1983 therefore is provided to create a context for what appears in the following chapters. For more details on historical Soviet space science, space applications, and military space programs, consult *Soviet Space Programs 1976–1980 (with supplementary data through 1983),* written for the Senate Commerce, Science and Transportation Committee and published by the Government Printing Office in 1985.[1]

Space Science

The Soviet Union has engaged in a modest program of space science activities throughout the history of its space program. These activities have included scientific satellites in Earth orbit for studying the atmosphere and Sun/Earth interactions, orbiting spacecraft for astronomical observations, lunar probes, and planetary missions to Venus and Mars.

EARTH ORBITAL SCIENCE

The Soviets use both free-flying spacecraft and space station crews to conduct space science activities. Historical information on the use of space stations for space science is contained in Part 1 of this report.[2]

Free-flying spacecraft for space science activities have been launched since 1957. The world's first satellite, Sputnik 1, is usually categorized as a space science satellite since observations of its beeping noise provided data on atmospheric density.

Many Soviet space science probes during the first two decades of the space program were given the generic designation "Cosmos" and little is known about them or the results achieved. There have been other scientific satellites as parts of series which the Soviets have openly discussed. Almost all of them have been for studies of solar-terrestrial interactions in the upper atmosphere and magnetosphere, and include the Proton and Elektron satellites in the mid-1960s, three Soviet/French satellites called Aureole (or Arcad)

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[1] The previous editions of this report are: Soviet Space Programs 1976–1980 (with supplementary data through 1983) Parts 1–3; Soviet Space Programs 1971–1975 (2 volumes); Soviet Space Programs 1966–1970; Soviet Space Programs 1962–1965; and Soviet Space Programs 1962. All were written for the Senate Commerce, Science and Transportation Committee, or its predecessor (in terms of jurisdiction over space matters), the Committee on Aeronautical and Space Sciences, and published by the Washington, U.S. Govt. Print. Off.

[2] U.S. Congress. Senate. Committee on Commerce, Science and Transportation. Soviet Space Programs 1981–1987. Part 1. Committee Print. Prepared by the Congressional Research Service. Washington, U.S. Govt. Print. Off., 1988.

launched between 1971 and 1981, and the on-going Interkosmos and Prognoz series. Through the end of 1983, there had been 22 Interkosmos and 9 Prognoz satellites. The ninth Prognoz, and one satellite called Astron that apparently is not part of a series, have been for astronomical observations. Two of the Interkosmos satellites were for oceanographic studies.

Interkosmos Satellites

In 1967, the Soviet Union opened its space program to international cooperation through the creation of the Interkosmos Council in the Soviet Academy of Sciences. There are 10 members of Interkosmos,[3] and they participate in the development of scientific spacecraft and analysis of resulting data. Satellites developed cooperatively by the members of Interkosmos are often given the Interkosmos designation.

Twenty-two Interkosmos satellites were launched from 1969 to 1983. They are single-purpose spacecraft somewhat similar to the U.S. Explorer program. With only two exceptions, they were designed to study solar-terrestrial interactions in the Earth's upper atmosphere and magnetosphere. Beginning in 1976 with the launch of Interkosmos 15 in 1976, a new spacecraft design was used which provided greater volume and weight for scientific instruments.

Some of the more interesting missions were Interkosmos 18, launched in 1978, which involved the use of a sub-satellite developed by Czechoslovakia called Magion. Magion was separated from the main spacecraft after it attained orbit, and followed a trajectory close to the mother craft, providing a second set of data that allowed scientists to separate temporal factors from spatial factors in their analysis. Interkosmos 20 and 21, launched in 1979 and 1981 respectively, were a departure from previous missions because they focussed on oceanographic studies. Interkosmos 20 also was used to relay data from ocean buoys and platforms to the ground control center. The 1981 launch of Interkosmos 22 returned the program to studies of solar-terrestrial physics. This satellite was also called Bulgaria-1300 to celebrate the 1300th anniversary of the founding of Bulgaria and involved a number of Bulgarian experiments.

Prognoz

Between 1972 and 1983, nine Prognoz satellites were orbited. The first eight Prognoz satellites, like most of the Interkosmos satellites, were related to solar-terrestrial research, including measurements of the interplanetary medium. The satellites were all placed in highly elliptical orbits, and weighed approximately 1 metric ton. Many carried experiments from other countries (notably France, Sweden and the Interkosmos countries). Among the uses of the Prognoz data have been studies of how cosmic rays penetrate spaceship cabins and forecasting favorable times for launching spacecraft.

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[3] In addition to the Soviet Union, the members are: Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Mongolia, Poland, Romania, and Vietnam. Other countries cooperate with the Soviets on some space projects, often through the Interkosmos Council, but they are not members of Interkosmos.

Prognoz 9 was used for radio astronomy studies of the universe and was launched in 1983 into an orbit with an apogee of 720,000 km, well past the orbit of the Moon. In an experiment called "Relikt," the spacecraft searched for radiation surviving from the time the universe formed and the Soviets reported in 1984 that data from the Relikt experiment did not contradict contemporary theories of cosmology, but did differ substantially from a model map that had been compiled based on other data. Specifically, the Soviets reported that their data showed the intensity of radiation in the central part of the new map, on both sides of the vertical axis of symmetry, to be 10 times higher than anticipated.[4]

Astron

In 1983, the Soviets launched the Astron satellite for x-ray and ultraviolet astronomy studies. It was launched the same year as Prognoz 9, which gave the Soviets two astronomical satellites simultaneously, though they studied the universe in different wavelengths. Astron was still operating in 1988 even though it had only a one year design life, and articles describing the satellite appeared regularly in the Soviet press throughout its five years of operation. It is in a highly elliptical orbit with an apogee of 200,000 km.

Astron was used to study over 400 galaxies, stars, nebulae, pulsars, quasars and other objects of astronomical interest. According to a 1985 report, ultraviolet data from Astron had led to "radical changes" in previous ideas about the structure of the outer layers of stars.[5] Because of the satellite's long lifetime, astronomers were able to make repeated observations of the same objects to determine how they change over time.[6]

Among the objects of special interest were observations of Comet Halley in late 1985 and early 1986, which supplemented data from the VEGA probes (see chapter 2). As Astron began its fourth year of operation in March 1987, the supernova in the Large Magellanic Cloud was discovered. Supernovas emit strong x-ray radiation, and Astron was the only x-ray satellite in orbit at the time. It was reprogrammed and reoriented to make observations.[7]

The satellite was still operating in March 1988,[8] but the Soviets had indicated that they expected it to end its useful lifetime soon. No further reports were found through the end of the year.

LUNAR AND PLANETARY EXPLORATION

The Soviets have never attempted to send probes to Mercury or to the outer planets beyond the asteroid belt. Instead, they have focussed on Venus, the Moon and Mars. They have been relatively unsuccessful with their Mars probes in the past, but they have enjoyed considerable success with the Venus and lunar probes.

Through the end of 1983, the Soviets had acknowledged sending 24 Luna probes to the Moon, 16 Venera probes to Venus, and 7

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[4] Krasnaya Zvezda, Dec. 19, 1986, p. 4.
[5] Pravda Ukrainy, Mar. 30, 1985, p. 4.
[6] Moscow Television Service in Russian, 2210 GMT, July 4, 1986.
[7] Moscow in English to North America, 2300 GMT, Nov. 26, 1987. By the summer of 1987, the Soviets also had the Kvant x-ray astronomy facility docked with the Mir space station which was used for supernova observations as well.
[8] Pravda, Mar. 24, 1988, p. 5.

Mars probes to Mars. There also were eight satellites in the Zond series that went to these destinations. During the early part of the space program, there were a significant number of spacecraft launches that Western analysts concluded were intended to reach the Moon, Venus or Mars, but which were unacknowledged by the Soviets and given generic "Cosmos" designations because they were failures.

The Moon

The Soviet lunar exploration program is entirely historical at this point since the most recent lunar probe was launched in 1976. A special analysis of the Soviet lunar exploration program is included as an annex to chapter 2. In brief, there were three generations of Soviet lunar probes: 1959, 1963–1966, and 1968–1976. Of the three first-generation spacecraft, two were successful: Luna 2 which struck the Moon, and Luna 3, the first spacecraft to return pictures of the far side of the Moon.

The 10 second-generation spacecraft were intended to make soft landings on the Moon or orbit it. Luna 4–9 (all launched in 1965) and Luna 13 (1966) apparently all were soft landers, but only Luna 9 and 13 were successes and the Soviets have not officially announced the intended missions for Luna 4–8. Luna 9 was the first spacecraft to make a survivable landing on the Moon. Luna 10–12, all launched in 1966, were orbiters, and all were successful. Luna 10 was the first spacecraft to orbit the Moon.

There were 11 third-generation Luna spacecraft. Six were intended to return samples of lunar soil to Earth and three did so successfully: Luna 16 in 1970, Luna 20 in 1972, and Luna 24 in 1976. The three unsuccessful sample returns were Luna 15 in 1969, Luna 18 in 1971, and Luna 23 in 1974. Luna 15 is notable because it was launched while the U.S. Apollo 11 crew was enroute to the Moon. Western analysts have speculated that the Soviets intended to "scoop" the United States by returning a sample of lunar soil using an automated spacecraft before the Apollo 11 crew could return. Luna 15 failed, however, and the Soviets have not officially stated what its purpose was. The three Luna spacecraft that did return samples brought back a total of approximately 300 grams (compared to 380 kilograms returned by the U.S. Apollo crews).

Two other spacecraft, called Lunokhods (launched on Luna 17 and Luna 20 in 1970 and 1973 respectively), were rovers that moved across the lunar surface, returning panoramic photographs and the results of on-site chemical analyses. The remaining three successful Luna probes were all orbiters: Luna 14 in 1968, Luna 19 in 1971 and Luna 22 in 1974.

Between 1968 and 1970, five spacecraft in the Zond series were launched to the Moon (Zond 3, a Mars probe, returned pictures of the far side of the Moon as well, see below). Zond 4, launched in 1968, was a diagnostic engineering test and was launched in a direction opposite from the Moon's location at the time, but to lunar distance. The Soviets did not indicate whether the mission was successful in achieving whatever goals it had. Zond 5–8 were circumlunar flights that were recovered back on Earth and were part of Soviet plans to send humans to the Moon. The four spacecraft landed in the ocean and each was successfully recovered. Biological

specimens were carried on Zond 5 and 6 (turtles, wine flies, meal worms and a variety of plants). The Zond was essentially a Soyuz spacecraft (see Part 1 of this study), and the Soviets announced that the flights were tests related to the goal of landing people on the Moon and returning them safely to Earth. These Zond spacecraft are the only Soviet probes to intentionally make water landings.

Mars

From 1962–1983, the Soviets launched seven spacecraft designated "Mars," the last in 1973. Two Zond spacecraft also seem to have been related to the Mars program. Zond 2, launched in 1964, passed Mars, but communications had been lost with the spacecraft. Zond 3, launched in 1965, was placed on a trajectory toward the orbit of Mars, but the launch was made without reference to a suitable launch window for Mars, and the planet was nowhere near the Zond when it achieved that distance. Communications were still being received when it reached Mars distance, however.

Of the seven Soviet spacecraft carrying the Mars designation, only one is considered a complete success by Western standards—Mars 5, an orbiter launched in 1973. Two others, Mars 2 and 3, are partial successes.

Mars 1, launched in 1962, apparently was a fly-by probe, but communications were lost with it before it reached Mars. The next attempt was in 1971 with the launches of Mars 2 and 3, each of which was a combination orbiter/lander. The Soviets gave landing coordinates for Mars 2, but no more was said about it, indicating that it failed. Mars 3 landed and returned data for approximately 20 seconds and then ceased transmitting for unknown reasons. The orbiters returned some data and therefore the missions are considered partial successes.

The next Soviet Mars attempt was in 1973. Because the planetary alignments were not as favorable, requiring more energy to reach Mars, the spacecraft were launched individually instead of as orbiter/lander combinations as had been done for the 1971 missions. Mars 4 and 5 were the orbiters, while Mars 6 and 7 were the landers. The braking rockets on Mars 4 and Mars 7 did not fire and the spacecraft continued past Mars. Mars 5 successfully achieved orbit and is the only completely successful Soviet Mars probe to date. Communications with Mars 6 were lost just before it touched down on the Martian surface.

Data from the Mars 2, 3 and 5 orbiters included photographs and temperature profiles of the surface, and atmospheric analyses.

Venus

In stark contrast to Mars, the Soviets have had excellent success with their Venus exploration program. Through the end of 1983, 16 Venera probes had been launched, along with one Zond.[9]

Zond 1, launched in 1964, was the only one in the Zond series related to Venus. Communications with the spacecraft ceased

[9] The results of many of the Soviet Venus probes, along with U.S. spacecraft that investigated that planet, are presented in: Hunten, D. M. et al., eds. Venus. Tucson, Univ. of Arizona Press, 1983.

before it reached the planet, however. The first two Veneras, launched in 1961 and 1965, were fly-bys and communications were lost before they reached Venus. Venera 3, launched in 1965, impacted the planet's surface as planned, but communications had been lost enroute to Venus. The next three in the series—Venera 4, launched in 1967, and Venera 5 and 6, launched in 1969—signalled a change in luck for the Soviets. They all successfully completed their missions of making atmospheric measurements during descent to the surface for a hard (non-survivable) landing.

The next series of probes were soft (survivable) landers. Climate conditions on the surface of Venus are severe, so a "survivable" landing means only that the probe transmits surface data after landing. All eight Soviet soft landers launched between 1970 and 1981 were successful, and one transmitted data for nearly two hours, much longer than planned.

Venera 7, launched in 1970, was the first to make a soft landing, transmitting strong signals for approximately 35 minutes. Venera 8 followed in 1972 and was the first of the series to carry soil analysis equipment, revealing that the soil contained potassium, uranium, and thorium. It transmitted surface data for 50 minutes.

Venera 9 and 10, launched in 1975, ushered in a new era of Venusian exploration. They were much larger than previous Veneras, and each was composed of two sections, an orbiter and a lander. The landers carried black and white cameras and returned the first photographs from the surface of another planet. The data surprised scientists who expected to find a dark planet (because of the heavy clouds) with a smooth, sandy surface on the assumption that the atmospheric pressure (90 times that on Earth at sea level) and temperatures (500 degrees C) would have eroded any rocks. Instead, lighting was found to be as bright as a cloudy summer day in Moscow, and rocks were clearly visible. This was one of the first clues that Venus was a geologically active planet. Subsequent observations by Soviet and U.S. probes have supported and vastly extended the Venera 9 and 10 results. The panorama extended out to 160 meters, and the horizon may have been 200–300 meters away. The landers transmitted data for 53 and 65 minutes respectively, using the orbiters as communications relays. The orbiters also made atmospheric studies.

Venera 11 and 12, launched in 1978, also had two sections, but instead of orbiters and landers, they had fly-by buses and landers. These missions were only partial successes. The fly-by section dropped the landers off at the planet and then continued past the planet, acting as communications relays during the almost two hours that the landers transmitted data from the surface, although the color cameras carried by the landers failed. The landers transmitted data for 110 and 95 minutes respectively, providing information on local climate conditions. During the descent, instruments on the landers made a wide variety of atmospheric measurements.[10]

Venera 13 and 14, launched in 1981, were similar, if not identical, to Venera 11 and 12. Landing sites were chosen based on radar

[10] The entire Sept.-Oct. 1979 issue of Kosmicheskiye Issledovaniya (Cosmic Research) was devoted to results of the Venera 11 and 12 flights, primarily the atmospheric measurements.

images from the U.S. Pioneer-Venus probe, demonstrating the growing cooperation between the United States and Soviet Union in exchanging data from planetary probes. In addition to color cameras, the landers carried soil sampling equipment. Data showed that Venus' surface is yellowish orange, with some green, and the atmosphere (reflecting the color of the surface) is primarily orange. A drill was used to obtain soil samples that were brought inside the spacecraft for analysis using an x-ray fluorescence spectrometer. Data showed that at the Venera 13 site, the rock was leucitic basalt with a high potassium and magnesium content, a type found on Earth in the Mediterranean volcanic area. The Venera 14 site was covered with rock corresponding to oceanic tholetic basalts which are widespread on Earth. The landers operated on the surface for 127 minutes and 57 minutes respectively. Atmospheric studies were also conducted during descent to the surface.

In 1983, the Soviets launched two more probes, Venera 15 and 16. Unlike any of the previous spacecraft, they were orbiters that carried synthetic aperture radars (no lander was carried). Data from these spacecraft have been used to make maps of the surface, which cannot be seen visually because of the clouds. The resolution on the radars was not particularly good (1–2 kilometers, about what can be obtained using the Arecibo radio telescope in Puerto Rico), but the spacecraft were in polar orbits around Venus, providing data on parts of the planet that cannot be seen from Earth. The probes returned data from October 1983 to July 1984, and a map showing the north pole of Venus was available in the West as early as February 1985, followed a month later by several presentations by Soviet scientists on the data at an international conference in Houston, Texas.[11] Additional photographs were released in 1986 and 1988.[12] Following the U.S. space shuttle Challenger tragedy, the Soviets named two of the craters they found on Venus after the two women astronauts who died.[13]

The Soviets made three general conclusions based on the results from Venera 15 and 16.[14] First, volcanism and horizontal movements of the planet's crust are mainly responsible for the geological patterns observed. Second, the tectonic style of Venus (the response of its crust to internal motions, heating and chemical and internal transformations) is different from both the Earth's and that of smaller planetary bodies such as Mars. Third, the number of impact craters from asteroids or comets provides evidence that the average age of the planet's surface is about 1 billion years, so the volcanism and tectonism are not recent, and weather and other processes that would obliterate the craters are extremely slow.

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[11] Soviet Venera 16 Radar Spacecraft Photographs Large Area of Venusian Surface. Aviation Week and Space Technology, Feb. 11, 1985. p. 70–71. Soviet Venera Data Show Radial Structures. Aviation Week and Space Technology, Mar. 18, 1985. p. 298.

[12] See: Aviation Week and Space Technology, Mar. 31, 1986 (p. 121), Feb. 8, 1988 (p. 33) and Feb. 22, 1988 (p. 48–49). Also see: Planetary Report (publication of The Planetary Society, Pasadena, California), Sept.–Oct. 1986.

[13] Planetary features are traditionally named after women. The two astronauts were Judith Resnik and S. Christa McAuliffe.

[14] Armand, N. A. et al. New Results from Venera 15 and 16. Planetary Report, Sept.–Oct. 1986. p. 8.

Space Applications

Although Soviet writers were quick to recognize the potential applications of satellites to a wide variety of practical uses, including communications relay, direct broadcast, weather observation, navigation and traffic control, study of Earth resources and development of permanently occupied space stations, the Soviets were initially slow to exploit space. Whereas the first U.S. communications satellite, Project Score, appeared in 1958, the year of the first successful U.S. space launch, equivalent Soviet flights were delayed until 1965. Thus, despite seemingly advanced space exploitation technology, the Soviet Union did not move as rapidly from first flights to operational systems as the United States.

Communications

With its vast underdeveloped areas, the Soviet Union benefits greatly from communications satellites. Regions which are remote and difficult to access are interconnected by satellite without the expense of laying cable through difficult terrain to operate under harsh weather conditions. In view of such geographic and economic advantages, it was not surprising that the first domestic satellite distribution system in the world was the Soviet Orbita system. Today, reliable telephone and television services have been brought inexpensively to all parts of the Soviet Union.

As early as 1945, it had been shown that almost complete global coverage could be obtained with three satellites spaced at 120° intervals around the Equator at an altitude where they appear to be stationary in the sky to an observer on the Earth's surface.[15] Since the southernmost Soviet launch site at Tyuratam is at latitude 46°N, the Soviets lacked the capability to launch satellites into such orbits until they had developed the Proton, or D-1e, launch vehicle. This fact, together with poor coverage of the northernmost parts of the Soviet Union, from which satellites in geostationary orbit are viewed at very low angles of elevation, prompted the development of the Orbita system using Molniya satellites in semi-synchronous elliptical orbits.

The Molniya and Orbita Systems

Following an engineering test mission with Cosmos 41 in August 1964, the first Molniya 1 (Lightning) satellite was launched the following April. It had a cylindrical body terminating in a conical correction engine. At the opposite end was a windmill-shaped solar cell array of six panels and two steerable parabolic dishes. The 8th, 9th and 10th Molniya 1's constituted a three-satellite system with orbital planes spaced at approximately 120° intervals providing a complete 24-hour coverage of the Soviet Union. A four-satellite system with 90°-spacings was introduced with the 11th Molniya-1. An eight-satellite system with 45°-spacings began to be established when the 33rd Molniya 1 was placed mid-way between the planes

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[15] Clarke, A. C. Extra-terrestrial Relays. Wireless World, Oct. 1945. p. 305-308.
A satellite at a mean height of 35,787 km above the Earth's surface rotates in its orbit at the same rate at which the Earth rotates in its orbit about the Sun. Such an orbit is said to be geosynchronous. When a geosynchronous orbit is established in the equatorial plane it becomes geostationary.

occupied by the 27th and 29th Molniya l's. By the end of 1983, 59 Molniya 1 satellites had been successfully orbited.

The first of 17 Molniya 2 satellites was launched toward the end of 1971 and the last in February 1977. Although similar in size and appearance to the Molniya l's, these had additional solar panels providing some 50 percent increase in available power and clusters of horns replacing the parabolic dishes due to the change to the higher frequencies employed. The first two Molniya 2 satellites were placed in planes mid-way between the four well-established Molniya 1 planes, but the last 14 launches placed their satellites into the four main planes.

When Molniya 3 satellites were introduced, they joined satellites in the main planes over a 13-month period between November 1974 and the end of 1975. At that time, the system comprised four groups, each of three satellites, following each other at approximately six-hour intervals. The 21st Molniya 3 entered a plane midway between the main planes when it was launched at the end of August 1983. To date, no model of a Molniya 3 has been put on display and it is probable that the only differences between it and Molniya 2 are internal improvements. A photograph in a 1987 Soviet publication,[16] purporting to show a Molniya 3 on display in a Moscow museum, is indistinguishable from the earlier Molniya 2. However, a visit to the museum disclosed that the caption still describes the model as Molniya 2.[17] By the end of 1983, 22 Molniya 3 satellites had been successfully orbited.

Orbita is the name used to describe the total complex of ground stations used in conjunction with dedicated communications satellites. Each can receive television transmissions relayed through geostationary and Molniya satellites, with further relay to surrounding areas. Additionally, the Orbita stations can receive and transmit telephone, telegraph, facsimile, and weather data via the Molniya satellites. The first phase of the installation of Orbita stations was completed by 1966. A special effort was made to have the Orbita system operational over much of the country in time for the celebration of the 50th anniversary of the Soviet Union in the fall of 1967. Another concentrated effort to add stations in more remote regions of the Arctic and eastern Siberia was made before the celebration of the centenary of Lenin's birth in 1970. By the end of 1981, some 90 stations had been installed and, in 1983, the head of the television department of the Ministry of Communications commented that the construction of receiving stations of the Orbita type for purely television purposes had been virtually stopped.[18]

An orbital period of around 717.75 minutes is chosen so that the ground-track repeats itself, albeit some 4.5 minutes earlier each day. The combination of orbital period with an eccentricity of approximately 0.74 produces apogee and perigee heights of 39,734 kilometers (km) and 609 km respectively. Apogee is placed to give maximum communications coverage in the Northern Hemisphere across the vast expanse of the Soviet Union. The low velocity near

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[16] Space Technology Serves Economic Needs. Novosti Press Agency Publishing House, 1987. p. 35.

[17] Ranft, C. H. Private communication.

[18] Dudkin, Valeriy. Soviet Weekly (London), Feb. 12, 1983. p. 8.

perigee (approx. 1.5 km/second) and an apogee height exceeding six Earth-radii gives periods of up to eight hours mutual visibility between Vladivostok in the east and Moscow in the west. Moreover, during this time, the satellite is visible from most points of the Soviet Union. A considerable part of the second orbit of each 24 hours is also visible from the Soviet Union across the North Pole. The use of inclinations close to 63.4° ensures that perigee remains deep in the Southern Hemisphere throughout the active life of the satellite. The roof of each circular Orbita station serves as the foundation for the fully rotatable, 12 meter parabolic antenna which tracks the satellite as it moves slowly through apogee.

Geostationary Communications Satellites

In February 1969, the Soviets logged information with the International Frequency Registration Board (IFRB) of the International Telecommunication Union (ITU) in Geneva relating to a Statsionar satellite to be placed over the Equator between 75° and 85°E. The following year, the date given for Statsionar to become operational was December 1, 1970. However, the first Soviet geostationary launch did not materialize until March 1974 with an engineering test named Cosmos 637. Later that year a spacecraft designated Molniya 1-S was placed into geostationary orbit at a location which gave coverage of Eurasia, Africa and Australia. A third geostationary launch in 1975 was given the designation Cosmos 775, which may or may not have been used to cover up an element of failure.

At the end of 1975, a new communications satellite named Raduga (Rainbow) was placed at the Statsionar 1 location. Although 13 Radugas had been launched by the end of 1983, no model of a Raduga has been publicly displayed nor pictures published, possibly because Raduga is very similar to Molniya.

It soon became apparent that Statsionar was the name of a specific location in the geostationary belt and not the name of a particular type of spacecraft. Radugas 1, 2 and 5 were placed at the Statsionar 1 location, Radugas 3, 4, 6, 8 and 9 were placed at Statsionar 2 (35°E) and Radugas 7 and 10 were located at Statsionar 3 (85°E). At the end of 1981, Raduga 11 was placed at Statsionar 2 and Raduga 6 was moved to establish the Statsionar 9 location (45°E). In 1983, Raduga 7 was relocated to become the first satellite at Statsionar 8 (25°W). Following this, Raduga 12 was launched to join Raduga 10 at Statsionar 3 and Raduga 13 joined Raduga 6 at Statsionar 9.

The first Ekran (Screen) satellite was launched at the end of 1976 and a model was displayed at the 1977 Paris Air Show at Le Bourget. Ekran is a direct broadcasting satellite employing a large rectangular helical antenna array. Eleven Ekrans had been launched by the end of 1983 and all had been located initially at the Statsionar-T location (99°E).

The 200 watt power of the Ekran satellite's transmitter, compared with the 30–40 watts of the other communications satellites, permits simplified design of the ground receiving station antenna and receiving equipment. Yagi arrays are used instead of the large dish antennas of the Orbita system. By the end of 1981, the Ekran receiving network had nearly 2,000 stations with their own relay

equipment bringing territories inhabited by 20 million people into the Soviet Union's main television network.

A third name for a geostationary satellite appeared with the launch of the first Gorizont (Horizon) at the end of 1978. This satellite failed to achieve a true geostationary orbit, but the second Gorizont was successfully located at Statsionar 4 (14°W), as were Gorizonts 4 and 7. Gorizont 3 was placed at Statsionar 5 (53°E) and was later joined by Gorizont 5. At the beginning of 1982, Gorizont 2 was moved to establish the Statsionar 6 location (90°E) and Gorizont 6 was launched to that location later that year, followed by Gorizont 8 in 1983. Models of the Gorizont satellites were displayed at the 1979 and 1981 Paris Air Shows. Gorizont's cylindrical body and annular thermoregulator are similar to those of Ekran, but it has a different solar array configuration, global coverage horn antennas, spot beam antennas and a 1 meter diameter dish antenna.

In addition to the two missions mentioned above, the Cosmos designation has been applied to another satellite which, by virtue of its precise stationkeeping ability, cannot be regarded as a failure. The launch announcement for Cosmos 1366 in May 1982, referred to the "testing of experimental equipment operating in the centimeter-band for relaying telegraph and telephone information" in addition to the usual scientific instrumentation. The satellite was placed at 80°E in the Statsionar 13 location, originally used for Statsionar 1.

IFRB notices have provided details of frequencies and locations planned for Volna (Wave), Volna-S, Gals (Tack), Luch (Beam) and Luch-P. These appear to be names of transponders hosted onboard Raduga and Gorizont satellites providing services for air, sea and land mobile communications, government/military communications and general communications

Progress in technology permitted the development of the Moskva system which, in conjunction with a network of microwave links and land lines, enables both First and Second Programs of Central Television to be relayed to a vast area. The station with its 2.5 meter dish antenna is small and does not require a special building for its accommodation.

International Links

Intersputnik

The Soviets unveiled plans in 1968 for an international consortium to be known as Intersputnik which would rival the Intelsat system in providing communications services and, three years later in Moscow, nine eastern bloc countries signed the agreement to establish the system. The first direct television transmission from the Soviet Union to Cuba was made on November 7, 1973.

In a 1981 article marking the lOth anniversary of the signing of the Intersputnik agreement, Pravda reported that ground stations were operating in the Soviet Union, Cuba, Bulgaria, Hungary, Vietnam, East Germany, Mongolia, Poland and Czechoslovakia. Vietnam was not one of the original signatories and Romania was omitted from the list. Gorizont satellites had taken over from the Mol-

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niyas and more than 40 percent of all television programs exchanged on Intervision relays were sent by satellite.[19]

At a meeting in Havana in March 1981, attended by the original signatories and delegations from Afghanistan, Algeria and Vietnam, a protocol between Intersputnik and Intercosmos was signed, calling for the scheduling of joint tests of space equipment.[20] An agreement on the construction of an experimental center in Dubna (Soviet Union), where work would be carried out in space communications, was drafted and signed at a standing working group on communication matters, held in Krakow (Poland) in September 1981.[21] At a meeting of the council of Intersputnik held in the following month in Brno (Czechoslovakia), delegations from Laos and Syria reported decisions taken by their governments to join the organization. The participants also discussed the development of ground-based long-range space communications in those two countries, Afghanistan and Iraq.[22]

In December 1981, the Intersputnik system embraced 12 ground stations. Eight of them, situated in Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Poland, the Soviet Union and Algeria, were linked by the Statsionar 4 satellite (Gorizont 4) and the remaining four, situated in the Soviet Union, Afghanistan, Vietnam and Mongolia, operated through the Statsionar 5 satellite (Gorizont 3). More than 20 countries were said to exchange television programs via the Intersputnik system with about as many using the system for telephone and telegraph communications.[23]

In September 1982, it was reported that, by late 1983, Nicaragua would have direct communications with the socialist countries through Intersputnik and that the Soviet Union would give financial support supply the ground station equipment and train Nicaraguan personnel.[24] The session of the Intersputnik council, held in Sofia (Bulgaria) in November was attended by a representative of the Yemen.[25]

At the 12th session of the Intersputnik council held in Tashkent during October 1983, plans were announced to build new ground stations in the Yemen, Syria, Kampuchea, Nicaragua, Grenada and other countries,[26] in addition to the 14 already functioning.[27] A draft agreement with the ITU, reflecting the interests of both sides, was approved.[28] Experts from Japan and Sri Lanka also attended.[29]

Inmarsat

As early as 1966, the delegations of the United States and the Soviet Union to the newly established Inter-Governmental Maritime Consultative Committee (IMCO) considered it advisable to at-

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[19] Pravda, Jan. 5, 1981.
[20] TASS, 1200 GMT, Mar. 17, 1981.
[21] PAP, 2100 GMT, Sept. 18, 1981.
[22] TASS, 1156 GMT, Oct. 26, 1981.
[23] Krasnaya Zvezda, Dec. 4, 1981.
[24] Radio Sandino, Managua, 1200 GMT, Sept. 17, 1982.
[25] TASS, 1006 GMT, Nov. 27, 1982.
[26] Moscow Home Service, 1600, Oct. 19, 1983.
[27] TASS, 1623 GMT, Oct. 21, 1983.
[28] TASS, 1606 GMT, Oct. 19, 1983.
[29] Tashkent Radio, 1700 GMT, Oct. 17, 1983.

tempt to solve maritime satellite communications problems on an international level. In accordance with a Soviet proposal, a Panel of Experts was set up in 1972, under the auspices of IMCO, to elaborate a concrete work program.

In 1976, the Soviet Ministry of Merchant Marine set up Morsviazsputnik (maritime satellite communications), an autonomous organization, charged with processing data received by means of Soviet and international satellites necessary for ensuring communication and navigation on the high seas.

The Convention and Operating Agreement on Inmarsat came into force in July 1979, once sufficient member-states (26) had subscribed 95 percent of the initial share capital. The first transmissions of information to merchant ships were successfully carried out in Vladivostok in July 1982, using Inmarsat's system of international communications satellites.[30] The first Soviet coastal earth station was built near Odessa on the Black Sea to operate through the Indian Ocean and Atlantic Ocean satellites.[31] A second station was planned in Nakhodka to serve the Pacific Ocean.[32]

Intelsat

The Soviet Union has ground stations in Dubna (near Moscow) and Lvov (in the Ukraine) for using the International Telecommunications Satellite Organization (Intelsat) and Inmarsat systems.[33] The Soviet Union does not belong to Intelsat, however. Two stations, one of which is the hot-line link between Washington and Moscow, access the Atlantic Ocean region satellites and a third gives access to the India Ocean region satellites.

Amateur Radio

Several Soviet engineers involved in the Apollo-Soyuz Test Project (ASTP), who also were radio amateurs, contacted some of the U.S. AMSAT members about amateur satellites during a visit to NASA's Goddard Space Flight Center, but nothing further was heard about Soviet amateur radio until an article about a terrestrial repeater appeared in the Soviet electronics magazine Radio in 1975. A notice on the Soviet amateur satellite service was filed with the ITU in 1977 and this was followed by a series of articles in Radio on the new Soviet RS (Radio Sputnik) satellites which were to be launched.[34]

RS 1 and RS 2 were launched along with Cosmos 1045 in October 1976. The results of these first two Soviet amateur radio satellites were summarized in a translation of articles in Radio in 1979.[35]

Iskra (Spark) 1, launched with Meteor 31 in July 1981, was a developmental satellite built by the Moscow Aviation Institute transmitting on 5.1 Gigahertz (GHz). Confusion surrounding its nature led to it being cataloged as a separate satellite. However, later evidence suggested that it remained attached to the rocket body,

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[30] Moscow Home Service, 2100 GMT, July 18, 1982.
[31] TASS, 1215 GMT, Nov. 19, 1982.
[32] Moscow for Seamen, 0030 GMT, Jan. 14, 1983.
[33] Moscow World Service, 1000 GMT, Feb. 17, 1982.
[34] Van Horn, L. Communications Satellites. Brasstown, NC, Grove Enterprises, 1986. p. 3-4.
[35] Labutin, L. The U.S.S.R. Radio Satellites. Telecommunication Journal, Oct. 1979. p. 638-639.

either by design or accident, and NORAD administratively "decayed" the individual satellite number for Iskra 1 from its satellite catalog four months after launch.[36]

Six RS satellites were launched by a single booster on December 18, 1981. All six used 2 meter to 10 meter mode A transponders and could be monitored on shortwave communications receivers. Transmitter powers were 5 watts. RS 3 and RS 4 were experimental in nature, containing beacons only, without communications packages. RS 5 and RS 7 each contained beacons and mode A and auto, or Robot, transponders. RS 6 and RS 8 each contained beacons and one mode A communications transponder. Telemetry of onboard parameters was transmitted in various frame-formats as Morse code groups of either one or two letters followed by two digits, prefaced with the call sign.[37]

In April 1983, it was reported that, in the past year, the satellites' relays worked for over 23,000 hours, enabling Soviet "hams" to establish some 16,000 QSLs (contacts). The automatic robots on the satellites had worked for about 9,000 hours enabling "hams" throughout the world to communicate.[38] The satellites were used as communications links by a Soviet polar expedition in the Antarctic. Contact was established with Brazil through RS 6, RS 8 and the robot of RS 7. RS 5 was used to send a telegram, which was delivered within 40 minutes, to Moscow.[39]

Two small Iskra satellites, of 28 kg mass, were manually launched by cosmonauts through the airlock of the Salyut 7 space station on May 17 and October 31, 1982. Iskra 3 had been brought to Salyut 7 in Progress 16. It is believed that both satellites carried transponder communications packages although there have been no reports of operations through them. Shortwave 10-meter beacons on both satellites were quite audible during their short lives before they decayed in the Earth's atmosphere.[40]

METEOROLOGY

The Soviets revealed the operational status of a "Meteor" system of weather satellites in June 1967,[41] but had been experimenting with meteorological payloads from the very beginning of the Cosmos program in 1962. In some cases, experimental packages were carried as supplementary payloads on recoverable photoreconnaissance satellites, while in other cases the complete payload had a meteorological mission. Examples of sensors and systems which were developed and tested within the Cosmos program include television and photometric determination of cloud cover, water vapor resonance attenuation, determination of humidity, infrared diffraction scanning photometers and semiconductor bolometers, microwave detectors of thermal radiation from the atmosphere and the Earth's surface, solar power supplies, aerodynamic stabilization, and electric motor-driven flywheels for altitude stabilization.

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[36] Johnson, N. L. Soviet Space Programs 1980–1985. San Diego, CA, Univelt Inc., 1987. p. 93.
[37] Davidoff, M. R. The Satellite Experimenter's Handbook. The American Radio Relay League, Newington, CT, 1984. p. RS(1)–RS(2).
[38] Moscow North American Service, 2300 GMT, Apr. 15, 1983.
[39] TASS, 1600 GMT, Apr. 13, 1983.
[40] Van Horn, L. op. cit., p. 6.
[41] TASS, 1525 GMT, June 1, 1967.

The results of all this research and development were brought together in five missions culminating with Cosmos 122, launched in mid-1966, although this was not acknowledged as a weather satellite for several weeks.[42] The Soviet Union and the United States already had an agreement to exchange pictures gathered by weather satellite over the so-called "Cold Line" between Moscow and Suitland, Maryland, and, after some months of experimenting with Cosmos 122, poor quality pictures which were too late for real-time forecasting were transmitted on a selective basis for a few weeks until the payload failed.

Cosmos 144, launched at the end of February 1967, heralded a change of launch site from Tyuratam to Plesetsk and a change of inclination from 65° to 81.2° with a near-circular orbit at 650 km. This, and its four successors, were improvements over Cosmos 122, operating continuously instead of intermittently, having solar arrays of increased area, and were specifically identified soon after launch as operational weather satellites.

Initially, the data were recorded and stored for transmission by radio down-link when the satellites were within range of one or more of the three receiving centers at Moscow, Novosibirsk or Khabarovsk. Later satellites carried automatic picture transmission (APT) equipment making real-time pictures available anywhere within receiving range.

Individual satellite pictures are fitted together to create a large photo-mosaic of the area under study. The data are not only used by the Soviet Hydrometeorological Service, but are instantly relayed to the World Meteorological Service.

The Soviet Union signaled the completely operational status of the Meteor system in 1969 when it began naming certain satellites Meteor, without further designation by number. Westerners, for convenience, add numbers to the Meteor name and recent Soviet publications have adopted the same practice.

The orbits of the first four Meteors were similar to those of Cosmos 144, but the fifth Meteor was the first to operate in the higher, 900 km, 102 minute orbit which was to become standard with the launch of the tenth Meteor at the end of 1971. Details of the construction of a Meteor satellite were published in 1979.[43]

Television equipment was used for making cloud cover observations on the daytime side of the Earth. Infrared equipment was used for cloud cover observations on the nighttime side. Actinometric apparatus registered the radiation fluxes emanating from the Earth enabling computation of the heat "budget" of the planet, determination of the temperatures of the land and ocean surface, calculation of the moisture content of the atmosphere and demarkation of the boundaries of ice cover.

Twenty-six of the first 29 satellites with the Meteor designation were standard weather satellites. The 18th, 25th and 28th were said to be experimental. The last was the first of the sun-synchronous launches from Tyuratam and was followed in that regime by the 29th, 30th and 31st Meteors. These were the forerunners in the Earth resources satellite program.

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[42] Izvestiya, Aug. 19, 1966, p. 4.
[43] Marchenko, M. Tekhnika Molodezhi, 1979. p. 23.

The first of an improved operational system, Meteor 2, was launched on July 11, 1975, coming between the 21st and 22nd of the original Meteors. The last of the original Meteors with a posigrade orbit, the 27th, was launched after the second Meteor 2. The second generation satellites had improved systems[44] and the first seven, 9th and 10th flew in the standard 81.2°, 102 minute orbit of the old Meteors. The 8th Meteor 2 signaled the introduction of the F-2 as the launch vehicle for the system and the higher, near-circular 950 km orbit at 82.5° inclination produced an orbital period of approximately 104 minute.

Details of the instrumentation of Meteor 2 satellites and the type of information they produce were provided in a 1981 paper developed for the 1982 UNISPACE conference sponsored by the United Nations.[45] In a 1983 report detailing factual data on Soviet space activities in the interests of development of national economy, it was claimed that the "space system Meteor, used in making various weather forecasts, every year ensures a [saving] of 500–700 million rubles." [46]

Although the Soviets committed themselves to provide a geostationary operational meteorological satellite (GOMS) by the end of 1978 to support the Global Atmospheric Research Program (GARP), the Soviet Union withdrew from the commitment late in 1977. Although a GOMS has yet to appear, such a system is still registered with the ITU and, in fact, has been expanded to embrace three locations.

Academician N.N. Sheremetyevskiy, director of the All-Union Scientific Research Institute of Electromechanics of the Ministry of the Electrical Equipment Industry acknowledged that work on the creation of a geosynchronous satellite for meteorologists had "dragged on" due to the complexity of the adopted design. In a 1988 newspaper interview, he expressed the hope that the work would be completed in 1989 and that meteorologists would receive a satellite "up to the highest world technical standards." [47] He added that many interesting ideas would certainly be put into practice in the next five years.

REMOTE SENSING

The Soviet Union has steadily developed multispectral photographic, infra-red, microwave and radar sounders within the Meteor, Cosmos and Salyut programs to establish an impressive array of space platforms for the remote sensing of the world oceans and the Earth's natural resources. It has been estimated that remote sensing annually saves the Soviet economy some half a billion rubles by assisting "agriculture and forestry, geology and mineral surveys, hydrology and water resource management, oceanography and evaluation of marine resources, geography and control of the environment." [48]

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[44] Vetlov, I. P. Issledovaniye Zemli iz Kosmosa, 1980. p. 11–27.
[45] Soviet Space Programs: 1976–80, Pt. 3. p. 960, 970.
[46] TASS, 0712 GMT, Sept. 21, 1983.
[47] Izvestiya, Aug. 10, 1988.
[48] Yegorova, I. and Yu Zaytsev. Space for the National Economy. Politcheskoye Samoobrazovaniye, Moscow, Jan. 1984. p. 58–66.

Meteor-Priroda

The 18th Meteor, launched in July 1974, marked the beginning of the implementation of the Meteor-Priroda (Nature) experimental program. This, together with the 25th, 28th and possibly the 29th Meteor, were based on the first generation Meteor satellite.

Second generation satellites were used with the introduction of the Fragment imaging system on the 30th and 31st Meteors. Meteor 30, now almost eight years old, is still producing good imagery.

With these spacecraft, it became possible to receive multispectral TV pictures of the Earth's surface on a regular basis, to develop and test methods of transmission, reception and decoding of multispectral television information about natural objects, to check the correctness of the design and the efficiency of TV systems employing linear and conical optico-mechanical scanning and electronic pushbroom multi-element linear photodetector arrays, and to determine the requirements needed to be met by third-generation systems.

Landsat-Type Satellites

Cosmos 1484, launched in July 1983, was placed into a sun-synchronous orbit, similar to that employed by Meteor 30, but somewhat lower than that of the U.S. Landsats 4 and 5, and was a follow-on to the Meteor-Priroda series. The launch announcement spoke of instrumentation including optico-mechanical, scanning and television/equipment—wording identical to the description of Meteor-Priroda equipment. The Soviets now refer to this series of satellites as being of the Resurs-0 type. However, more recently, Arnold Selivanov of Glavkosmos, stated that the Resurs-0 type satellites had been placed in orbit since 1980.[49] Presumably he included the 30th and 31st Meteors in this series, but this raises the question as to why the designation was changed from Meteor to Cosmos. Since no photograph or drawing of Cosmos 1484 has been released and no model has been put on display, it is possible that it was not based on the Meteor satellite design. Radio transmissions, monitored in Sweden, were different from those of Meteor 30 and Meteor 31.

Oceanographic Satellites

Also in 1983, Cosmos 1500 was launched, the third in a series of satellites for the Okean (Ocean) program. It was based on experience gained with Cosmos 1076 and 1151 and can be considered to be the first of the operational satellites of the Okean-0 type. A full-scale model of Cosmos 1500 was displayed at the 1985 Paris Air Show. A description of the spacecraft is given in chapter 3.

Cosmos 1500 was immediately effective in providing imagery enabling the freeing of Soviet merchant ships trapped by a sudden freeze of ice in the Chukchi and East Siberian Seas.[50] It was subsequently announced that Cosmos 1500 was equipped with side-look-

[49] Lenigradskaya Pravda, Dec. 31, 1987. p. 3.
[50] Moscow World Service, 2200 GMT, Nov. 10, 1983.

ing radar which had been installed for the first time on an oceanographic satellite.

Transmissions at 4 lines/second, discovered on 137.4 megahertz (MHz) in Italy, were shown to emanate from Cosmos 1500 and to be APT stored imagery of the Caribbean. Radar and visible imagery can be displayed contiguously and stored imagery has been used to compile mosaics of the polar ice-caps.

Recoverable Photographic Satellites

First indications of a series of film-return satellites with the objective of obtaining photographic data relating to the breakup of Arctic ice on the sea routes along the Soviet Union's northern coastline came in 1968 when two satellites, Cosmos 210 and Cosmos 214, flew at a new inclination of 81.3°. Both launches occurred in April and were not repeated that year. Further flights with this near-polar inclination followed in succeeding years, usually in pairs during April, but with each member of the pair having different resolution characteristics. As time passed, other flights appeared with this inclination at different times of the year, often associated with secondary scientific missions. One of these, Cosmos 771 in September/October 1975, was the first recoverable Cosmos satellite to employ a TK Morse code recovery beacon since the phasing out of the second generation photoreconnaissance satellites some two years earlier. These TKs came to be characteristic of high resolution missions with a photographic arc at a height of 220 km whereas TF recovery beacons were associated with lower resolution missions at 275 km through the photographic arc.

The launch announcement for Cosmos 912 in May 1977, identified its mission as continuing "the study of the Earth in the interests of different sectors of the national economy of the Soviet Union, and international co-operation." More and more such identifications appeared with the passage of time. Some of these incorporated the statement that "the incoming information is being turned over to the Priroda State Scientific Research and Production Center for processing and use."

A change of inclination to 82.3° took place in May 1980, with the launch of Cosmos 1182 and flights continue at this inclination to this day. There were seven such flights in 1981, seven more in 1982 and nine in 1983. Satellites of this type constitute the Resurs-F subset of the large state-wide Resurs (Resources) system.

A figure illustrating an article on Earth resources satellites in 1980 depicts a three-tiered system in which Salyut space stations operate at a level between the higher Meteor-Priroda type spacecraft and the lower film-return Cosmos satellites.[51] The latter are depicted as having cylindrical instrument and engine sections supporting, in front, a capsule formed from two cones joined base to base with the one attached to the cylinder being truncated at approximately half its height. While this is obviously schematic and should be accepted with caution, it must be pointed out that the portrayals of the Salyut and Meteor-Priroda are good representations of the actual spacecraft.

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[51] Kiyenko, Yu P. Issledovaniye Zemli iz Kosmosa, 1980. p. 5–10.

The use of crews on space stations for remote sensing is dealt with in volume 1 of this report.

NAVIGATION

The Soviets advertised the existence of a navigation satellite system as long ago as 1966, but no Soviet satellite was specifically identified as having such a mission until the launch of Cosmos 1000 on March 31, 1978. Although no separate and distinctive name, such as Molniya and Meteor, has been given to later satellites in the series, a model of Cosmos 1000 was displayed at the 1979 Paris Air Show under the name of "Tsikada". Later, it was stated that the Tsikada navigation system was being created, based on Cosmos satellites, "to make it possible to determine the location of vessels at any point in the world's oceans, whatever the time of day and weather conditions." [52] The system would "shorten the duration of trans-oceanic voyages and give an annual economic benefit of hundreds of millions of rubles."

In the same way that the U.S. Navy developed Transit first for use with its Polaris submarines, and then by stages extended the use to other naval vessels before declassifying it and making it available to civilian users, the Soviet system developed within the Cosmos program as a military system before being extended for use by their research and merchant vessels.

The first operational system providing rudimentary global coverage, established between December 1970 and December 1971, consisted of three Cosmos satellites in near-circular orbits with periods close to 105 minutes and orbital inclinations of 74° with their orbital planes spaced at 120° intervals. Two replacement satellites were launched before this first system was phased out.

The second system, differing from the first in having an orbital inclination of 83° and a plane-spacing of 60°, was established between August 1972 and September 1973. Five replacement satellites followed before Cosmos 800, which replaced Cosmos 663 in February 1976, was placed into an orbital plane 180° away. This had the effect of moving the orbital planes of the second operational system away from those of the third system, which had been introduced with Cosmos 700 in December 1974 and was being extended to a six-satellite system with 30° plane-spacings. The near-polar inclination of 83° meant, in effect, that satellites in orbital planes spaced 180° apart were virtually in the same orbital plane, but travelling in opposite senses. Thus it was only necessary to cover an arc of 180° with the orbital planes to achieve complete global coverage. Six more replacements followed before the second operational system was phased out, probably in the fall of 1979.

Cosmos 700 did not fit the general pattern of replacement, having its orbital plane offset by 20° from Cosmos 627. Cosmos 726 was also offset from the second system and 120° away from Cosmos 700. When Cosmos 775 was placed midway between them in October 1975, there was once more a three-satellite system with 60° plane-spacings.

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[52] Moscow Home Service, 1800 GMT, Mar. 16, 1982.

Confirmation of the existence of two separate systems was obtained from the monitoring of their radio transmission which, although similar, had certain differences. The next launch in the series, Cosmos 778 in November 1975, signaled a further development. Placed midway between the planes of Cosmos 726 and 775, it marked the growth of the third operational system into a six-satellite system with orbital planes spaced at 30° intervals which, as such, continues to this day.

The navigation message was decoded, almost completely, by the Kettering Group.[53] Transmissions on frequencies close to 150 MHz were shown to be 50 bits s-1, transitionally encoded, floating-point binary notation, providing an ephemeris and identity number for the transmitting satellite and almanacs for the other operational satellites in the system.

Cosmos 883, launched in December 1976, had its ascending node in the hemisphere opposite to those of the third operational system and took the identity number 11 (military satellites take identity numbers one through nine). It was followed by Cosmos 926, identity number 12, with its ascending node also in the opposite hemisphere and separated by 45° from Cosmos 883. All became clear with the launch of Cosmos 1000, number 13, a further 45° away, and the first to be specified as performing a navigation mission. The launch announcement also made reference to civilian usage. The civilian navigation system was completed by Cosmos 1092, number 14, another 45° away, establishing a four-satellite system with 45° plane-spacing. It has been observed that all civilian Cosmos navigation satellites transmit on 150.00 MHz.

The GLONASS System

The United States decided that it would be useful to possess a navigation satellite system which provided three-dimensional data and began development of the Navstar Global Positioning System. Similarly the Soviet Union decided to develop their three-dimensional system, called GLONASS.

Since 1982, the Soviet Union has been conducting tests of such a system, employing passive range measurement. Although details of the system had been logged with the IFRB earlier that year,[54] the first launch was surprising—a triple payload in the Cosmos series launched by the Proton launch vehicle. From the initial parking orbit with a 51.6° inclination, the payloads were placed into 64.8° inclination, near-circular orbits, with periods close to 673 minutes. Cosmos 1413-1415 were not spaced regularly around the orbital plane, but drifted slowly apart from the common injection point. However, Cosmos 1414 made a small in-orbit maneuver revealing some propulsion capability and visual observations showed that Cosmos 1414 had a stable attitude.

The second launch in the series placed three more satellites into the same orbital plane, but the third launch, at the end of 1983, put Cosmos 1519-1521 into a plane separated by 120° from that of the first six. By the end of 1983, only Cosmos 1414 and 1491 had

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[53] Wood, C. D. and G. E. Perry. Phil. Trans. R. Soc. London A, 294, 1980. p. 307-315.

[54] International Frequency Registration Board (IFRB) Circular no. 1522, Special Section no. ARll/A/3, June 8, 1982.

maneuvered to stabilize their positions in locations phased at 45° intervals.

SEARCH AND RESCUE

In March 1977, a technical team from the Soviet Union was briefed by the U.S. National Aeronautics and Space Administration (NASA) at NASA's Goddard Space Flight Center on ways in which the Soviets might participate in the proposed NASA-Canada search and rescue (SAR) demonstration. A proposed experimental program was developed in which one or more Soviet satellites would be equipped with SAR transponders and Soviet ground stations would be established for SAR operations. In addition, the Soviet activity was to be compatible technically and on the same schedule with the NASA-Canadian program.

The Soviets developed a system called COSPAS (a Soviet acronym for "Satellite System for Locating Vessels and Aircraft in Distress") operating in close cooperation with Inmarsat, and COSPAS transponders were installed on the civil navigation satellites, Cosmos 1383 and Cosmos 1447. Although each of these satellites has been replaced as a navigation satellite, their COSPAS transponders still remain active today.

A Radio Moscow home service report at the beginning of 1983 made reference to the "Moscow information receiving center for the Poisk (Search) satellite system." [55] This name has not come into general usage. The center was reported to be testing a new type of emergency position indicating radio beacon (EPIRB) which would make it possible to determine the location of an accident to an accuracy of 2 to 3 km rather than the 10 to 20 km possible at that time. New information-receiving centers were to be built in Vladivostok and Arkhangelsk. Later that year it was reported that the project had already saved more than 30 lives.[56]

GEODESY AND MAPPING

A special subset of satellites, transmitting a two-tone tracking beacon on 19.994 MHz, existed within the third-generation of photoreconnaissance recoverable Cosmos satellites that apparently were related to geodesy and mapping. These satellites did not maneuver and had a TL Morse code recovery beacon at the end of their missions instead of the more usual TF or TK. Such flights appeared, in general, only two or three times a year at times close to the equinoxes and at different annual inclinations to the Equator. With the Sun overhead close to the Equator there would have been average illumination in both Northern and Southern Hemispheres. The Soviet Union has the need to be able to correlate the international mapping grids for precise targeting of its missiles with MIRVed warheads and it has been suggested that this is achieved by taking simultaneous photographs in opposite directions of ground targets and star backgrounds using laser technology.[57]

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[55] Moscow home service, 1500 GMT, Jan. 23, 1983.

[56] TASS, 1357 GMT, May 3, 1983. By the end of 1987, more than 1000 lives had been saved by COSPAS/SARSAT.

[57] Aviation Week and Space Technology, v. 113, Sept. 22, 1980. p. 14–15.

The Soviet Union and the socialist bloc countries have shown considerable interest in laser-ranging to satellites such as is done with the U.S. Lageos spacecraft. The two Soviet Lunokhods that traversed the lunar surface in the early 1970s were equipped with French laser reflectors, for example. In 1982, the Polish observatory at Borowiec near Poznan participated in the international "Arctic-Antarctic" satellite surveying program, using satellites in the Intercosmos series, for determining precisely a line of survey points on the Earth's surface which would form the basis "for all kinds of astronometric and astrophysical readings." [58] Interkosmos (the Soviet organization that coordinates international space cooperation) set up a network of laser range-finder stations throughout the world and in 1983 it was reported that Polish laser range-finders were in operation in Cuba, India, Egypt, Bolivia, Bulgaria and Vietnam. A precision of 10 to 20 centimeters in the range from Earth to satellite was claimed.[59]

The Soviets announced that Intercosmos 22 [Bulgaria 1300] was equipped with corner-cube reflectors of Bulgarian manufacture and that a similar system had been ordered by the Soviet Union for its Meteor satellites.[60] A new observatory was built at Alma-Ata in 1983 and it was said that its increased reliability of tracking objects in space would help seismologists forecast Earth tremors.[61]

There are other continuing series of flights within the Cosmos programme for which results are never published and which, therefore, may be presumed to be military in nature. Those in near-circular orbits close to 1,200 km with orbital periods of approximately 109 minutes, initially at 74° and later at 83°, are presumed to have a geodetic role critical for the precise targeting of missiles. The introduction of the F-2 launch vehicle heralded a new mission profile with a higher near-circular orbits close to 1500 km at 82.5° (Cosmos 1312 in 1981 and Cosmos 1410 in 1982) and 73.6° (Cosmos 1510 in 1983).

SPACE MANUFACTURING

Chapters with the titles "Foundry Above the Earth," "Other Materials Which Did Not Exist Before," and "Biology and Pharmacology in space" are to be found in a popular book with the title "Industry in Space," published in Moscow in 1978. The book highlighted the problems of using the conditions of high vacuum and microgravity and considered various uses such as obtaining materials with unusual physical-mechanical properties, large single crystals, and super-pure materials, including medicines.

As might be expected, initial efforts in these directions were confined to the piloted space program and details of work on Soyuz 6 (1969), ASTP (1975) and the Salyut 6 space station (1977-1981) were given in the previous edition of this review.[62] The work was developed further on the Salyut 7 space station (1982-1986) and is described in volume 1 of this report.[63] The use of automated satel-

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[58] PAP, 1400 GMT, Oct. 18, 1982.
[59] PAP, 0900 GMT, Jan. 20, 1983.
[60] BTA, 0825 GMT, Aug. 12, 1983.
[61] Moscow Home Service, 0900 GMT, Feb. 6, 1983.
[62] Soviet Space Programs: 1976-80, Pt. 3, p. 1010-1016.
[63] Soviet Space Programs: 1981-87.

lites for materials processing research began after 1983, and is described in chapter 3 of this volume.

An international conference of socialist countries, devoted to space metallurgy, was held in Jurmala (Latvian SSR) during May 1983 under the title Interkosmos-83.[64]

Military Space Activities

OBSERVATION MISSIONS

Reconnaissance is a general term encompassing a variety of techniques aimed at the collection of intelligence. Imaging techniques are usually referred to as photographic reconnaissance, but in addition to lens systems, include scanning radiometers and radar systems. Passive electronic intelligence gathering systems depend upon the reception of electromagnetic emanations from Earth-based radars and the interception of radio transmissions.

Photographic Reconnaissance

The announcement that Cosmos 4 had been recovered from orbit after a flight of only three days in 1962 signaled the inauguration of a continuing program of recoverable satellites within the Cosmos program accounting for almost half of all Cosmos launches. This figure has held good over the whole lifetime of the Cosmos program and the annual number of such launches has remained reasonably constant. As more and more of these short duration flights took place and few scientific results were reported it became natural to ascribe a military role to them. Recoveries were not announced by the Soviets, but payloads disappeared from orbit when their periods were still high enough to rule out natural decay.

Following an initial period of research and development, payloads were routinely recovered after flights of eight days. Orbital periods were chosen so that the gradual daily drift of ground-track every 16 revolutions made those on the eighth day coincident with those on the first, thus ensuring complete coverage of the whole area of the Earth situated between northern and southern latitudes of the same value as the inclination of the orbit to the equator. The rate of daily drift is a function of the cosine of the inclination and this was evident in the small differences in orbital periods chosen for the preferred inclinations of 81.3°, 72.9°, 65° and 51.8°. Even with the longer-duration missions, which were to follow as time went by, the criterion for complete coverage was still satisfied for the non-maneuvering search-and-find missions.

The trend toward longer missions is a direct corollary of a general improvement in photographic resolution. Use of longer-focal-length optics, providing increased resolution on the same film format, results in a narrower swath being recorded. Consequently, to obtain uninterrupted coverage with the requisite overlap, ground tracks must be more closely spaced. Since perigee heights have always been as low as possible, consistent with keeping atmospheric drag to a minimum, the closer spacing and lower orbital period is obtained by lowering the apogee.

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[64] Moscow Home Service, 0900 GMT, May 19, 1983.

Kettering Group monitoring of the in-flight radio transmissions and recovery beacons has enabled five generations of Soviet recoverable satellites to be distinguished. Recovery beacons take the form of a succession of pairs of Morse code characters transmitted on 19.995 MHz. The letter T is common to all variants of the recovery beacons, but the dash of the T has twice the duration of the dashes in the other characters (F, G, K, L or V).

First generation missions employed shortwave frequencies of 19.989 or 19.994 MHz and were frequency-shift keyed (fsk) with pulse-duration modulation (PDM). Variations in telemetry-frame format revealed sub-sets which could be associated with low-resolution missions for area surveillance or high-resolution missions for close-look surveillance. These satellites were phased out in 1978.

A new type of transmission, pulse-code modulated (PCM), on 19.150 or 19.300 MHz, consisting of groups of three Morse code characters, signaled the appearance of the second-generation satellites. These flew high-resolution missions between 1968 and 1974 and exhibited a maneuvering capability. This enabled the orbit to be stabilized on reaching the desired location so that the satellite followed the same ground track over the target on successive days providing a close-look facility.

The first generation satellites were reassigned to fly area-surveillance missions with an extended duration, usually of 12 days duration. These first-generation extended-duration missions persisted even after third-generation satellites replaced the second generation for the close-look missions in 1974. Since 1974, area surveillance has been achieved by flying third-generation satellites with much higher perigees and using interlaced coverage with ground tracks falling mid-way between successive ground tracks of the previous day. Drift once more ensured complete coverage, but each half of the target area was sampled on alternate days. The two high perigee Earth resources flights of 1981 employed triple interlacing, sampling each third of the target area at three-day intervals.

Third generation satellites were introduced in 1969 and are still currently operational, flying 14-day missions. They employ a different type of fsk transmission on 19.989 MHz, which appears to be a tracking beacon lacking any telemetric information. Latterly, these transmissions are activated only on one or two orbits, late in the day, when the satellite is southbound over the Soviet Union. Amplitude-modulated (AM) data is transmitted on command on 232 MHz in the VHF band. In these pulsed AM transmissions, 4 microsecond-long pulses are transmitted every 80 microseconds defining words in the telemetry format. Within each such interval a word-value pulse, whose position within the 80 microsecond word interval defines the particular word value, is transmitted. Such a system is pulse-position modulated amplitude modulation (PPM–AM). There is also a second mode with a word interval of 96 microseconds.

Recoverable Cosmos satellites which do not transmit on any shortwave frequency known to the Kettering Group first appeared in 1975 at the new inclination of 67.2°. Two of the first three fragmented in orbit, but these satellites are now seen to constitute a fourth generation of satellites which fly missions of four to six

weeks duration. At times there are two such satellites in orbit simultaneously. Telemetry transmissions on 240 MHz have been observed at both low and high data rates. These consist of a frequency-modulated (FM) spectrum, approximately 300 kHz wide, with most of the energy at the edges of the signal bandwidth, indicating a high modulation index. The modulating signal is probably an amplitude-modulated pulse train (PAM). The normal frame duration is 10 milliseconds and the normal frame comprises 32 words. Perigee heights are generally lower than for satellites of earlier generations, normally close to 175 km, but occasionally falling below 160 km, necessitating regular boosting to overcome drag and maintain orbit. Imagery is probably returned digitally from orbit and film capsules are returned to Earth during the mission. Recovery-beacon signals from these capsules have been recorded as Morse code TVs. These satellites are generally launched later in the day than those with 14-day missions to ensure suitable lighting conditions over the target area at the end of the flight and perigee is relocated to the southbound pass in the latter stages of those missions exceeding four weeks.

A fifth generation advanced reconnaissance satellite made its debut at the end of 1982. Cosmos 1426, at 50.6° inclination out of Tyuratam, flew for 67 days before disappearing from orbit while its period was still sufficiently high to rule out natural decay. During its mission it made 10 major maneuvers, keeping the perigee continually in sunlight at a height close to 200 km.[65] Despite repeated attempts, the Kettering Group has failed to detect any shortwave or VHF transmissions from this satellite or its successors.

As reported in the space applications section of this chapter, two subsets of these recoverable payloads fill Earth resources and geodetic roles. Although the latter missions are no longer launched, products of the remote sensing flights are now made available commercially. Because their telemetry transmissions are indistinguishable from the military satellites, they may serve a dual purpose.

From the inauguration of the Cosmos program in 1962, recoverable payloads have been orbited by the A–1 and then, following the introduction of a more powerful upper stage in 1963, solely by the A–2 since 1968.

It is difficult to make estimates of the degree of resolution that is obtainable without access to the actual imagery. Claims that satellites can read newspaper headlines from orbit would seem to be wildly exaggerated. Photoscales of 1:3,000,000 for the search-and-find type of mission, 1:250,000 for quick-look coverage, and 1:50,000 for close-look missions represent reasonable estimates. With a moderate film resolution of 35 to 50 lines/millimeter for a low-contrast target, it should be possible to make out the general outline of small vehicles such as automobiles or even small continuous features such as well-used footpaths.

Identification of the targets for these photographic reconnaissance missions is not generally possible due to the fact that, during the duration of their mission, they overfly most of the inhabited areas of the globe. However, at times of crisis, it is sometimes possi-

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[65] Johnson, N. L. op. cit., p. 47.

ble to deduce Soviet interest by noting maneuvers which produce stabilized ground tracks which repeat themselves on a daily basis. Taken together with the perigee location, these provide 16 specific longitudes around the small circle of the perigee latitude. As perigee is usually located in the northern hemisphere, many of these lie within the Soviet Union or in the Atlantic or Pacific Oceans. One of the small number remaining after those have been eliminated may coincide with an area of political unrest. By proceeding along such lines of argument it was possible to show that Cosmos 463 and Cosmos 464 monitored the situation during the Indo-Pakistani war at the end of 1971 and to follow the intensive monitoring of the Yom Kippur war in 1973.[66] Bhupendra Jasani of Sweden's SIPRI Institute drew attention to the role of Cosmos 932 in alerting the world to the preparations for an atmospheric test of a nuclear device in the Kalahari Desert by the Republic of South Africa in 1977.[67]

Observations By Cosmonauts

Cosmonauts in Soyuz spacecraft and onboard the Salyut and Mir space stations make routine photographic observations of areas of particular interest using cameras such as the KATE-140 and MKF-6. These were described in part one of volume one of this report. The majority of cosmonauts are, or have been at some time, active military personnel. It would, therefore, be surprising if they did not, on occasions, take photographs and make visual observations at the request of the military command.

Radar Ocean Reconnaissance Satellites (RORSATS)

Cosmos satellites with orbital periods of 89.6 minutes and inclinations of 65° but differing from recoverable photographic reconnaissance satellites by having their perigees around 250 to 260 km, appeared with Cosmos 198 in 1967. Commencing with Cosmos 651 and Cosmos 654, these satellites operated in pairs and stationkeeping was rigidly enforced. Orbital planes were co-planar and a 23-minute time difference was maintained during the operational phase so that ground tracks were displaced by some 6° in longitude from each other.

Launched by the F-lm, this type of satellite does not separate from the second stage on being placed into orbit. Following an operational phase during which micromaneuvers maintain a circular orbit close to 260 km against the effect of atmospheric drag, part of the payload separates from the second stage and is boosted into a much higher circular orbit from where it will not reenter for several hundreds of years. This part contains a nuclear reactor, fueled with 50 kg of enriched U235, for providing the power for a side-looking radar using a slot antenna or planar array when in the lower orbit. Such satellites, using radar for ocean reconnaissance of the deployment and movements of western fleets, are known as RORSATs.

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[66] Perry, G. E. in Soviet Space Programs: 1971-75. Committee on Aeronautical and Space Science. U.S. Congress. Senate. Washington, 1976. p. 464-473.

[67] Jasani, B. SIPRI Yearbook 1978: World Armaments and Disarmament. London, Taylor and Francis, 1978. p. 73-79.

Cosmos 952 and Cosmos 954, launched in September 1977, operated as a pair. Cosmos 952 separated its reactor and transferred it to the "safe" orbit on October 8, after 22 days of operation. Cosmos 954 malfunctioned, however. It continued making small maneuvers until the early part of November 1977, but then entered a regime of natural decay and Western analysts expected that it would reenter the atmosphere some time in the following March. However, it lost altitude stability on January 6, 1978, and the rate of decay accelerated. It reentered over northern Canada on January 24, spreading radioactive debris over a wide area. The area affected is relatively unpopulated, and there were no confirmed injuries. Canadian authorities, assisted by the United States, cleaned up the debris and, under the Convention on International Liability for Damage Caused by Space Objects, charged the Soviets $6 million for the clean up activities. After several years, the Soviets agreed to pay half that amount.

No further satellites in this category were launched until Cosmos 1176 on April 29, 1980, more than two years later. Cosmos 1249 and Cosmos 1266, launched in 1981, were the first pair of RORSATs since Cosmos 952 and Cosmos 954 in 1977. It would appear that Cosmos 1266 quickly malfunctioned because its nuclear reactor was raised to the "safe" orbit after only a few days. It was noticed that, as with Cosmos 1176, two pieces appeared in the high orbit whereas, prior to the Cosmos 954 accident, only one piece had been cataloged. Cosmos 1299 flew a two-week mission later that year, coinciding with large-scale naval maneuvers by both NATO and Warsaw Pact countries.[68]

There were four RORSAT launches in 1982. Cosmos 1365 was launched on May 14, well after the British Task Force had reached the Falkland Islands. Possibly its imminent launch was taken into consideration for potential coverage of the area surrounding the Islands when Cosmos 1355 was launched on April 29 into a plane bearing little relation to previous satellites of that type. (See EORSATs in the section which follows). Cosmos 1372 was co-planar with Cosmos 1365, but some 38.5 minutes behind it, producing a form of triple interlacing of their respective ground tracks. These two satellites operated as a pair for a record 71 days.

Cosmos 1402 replaced Cosmos 1372 and, for a time, operated in partnership with Cosmos 1365. Cosmos 1365 was eventually replaced by Cosmos 1412, only 25.5 minutes behind Cosmos 1402, producing simple interlacing of ground tracks. Cosmos 1365 operated for a record 136 days before being separated into its individual components and having its reactor raised to the "safe" orbit. Cosmos 1412 ended its operational phase after 40 days on November 10.

Cosmos 1402 continued operating until December 28, 1982, when it split into three components, all of which remained in low orbit. The world's media became aware of the situation on January 5, 1983, and, mindful of the Cosmos 954 incident, gave maximum publicity to the story. One piece, cataloged as "B" by NORAD, decayed rapidly, leaving pieces "A" and "C" in decaying orbits. Eventually

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[68] Johnson, N. L. op. cit., p. 115-116.

the Soviets admitted that the satellite was out of control and emphasized that all precautions had been taken to ensure that no parts reached the Earth's surface.[69] One week later they disclosed that the two parts remaining in orbit were the main section of the satellite and the fuel core of its reactor.[70] It was immediately clear that the reactor core was the more dense piece "C" which was decaying at a slower rate than "A" and that the two pieces observed in the "safe" orbit since the resumption of the program in 1980 were indeed a reactor and its separated fuel core. The main part decayed over the Indian Ocean on January 23 and the fuel core over the South Atlantic on February 7. The RORSAT program did not resume launches until June 1984 (see chapter 4).

Electronic Intelligence Gathering (ELINT)

The mission of an ELINT, or ferret, satellite is to pinpoint locations of enemy defense radars, particularly those lying deep within enemy territory, and determine their ranges and signal characteristics. With such knowledge it becomes possible to design electronic countermeasures (ECM) and plan methods for penetrating the defenses. ELINT satellites are also used to locate military transmitters and to intercept military communications traffic.

Electronic Ocean Reconnaissance Satellites (EORSATs)

Soviet ELINT satellites dedicated to monitoring the activities of Western fleets at sea, known to DOD analysts as EORSATs (electronic ocean reconnaissance satellites), first appeared at the end of 1974. Equipped with small thrusters to overcome atmospheric drag, they make many small maneuvers to maintain their orbital period of 93.3 minutes in circular orbits at 65° inclination. In recent years they have operated in pairs with carefully chosen ground tracks lying precisely mid-way between those of their partners. When natural decay takes over at the end of their active lives, some have been raised to higher orbits, removing them from their replacements, and it is not unknown for fragmentation to occur at a later date. EORSATs and RORSATs both transmit PPM-AM on 166 MHz.

EORSATs, like the RORSATs, are launched from Tyuratam by the F-1m launch vehicle. Nicholas Johnson has pointed out an inter-group relationship between the EORSATs and the RORSATs in that their orbital planes always differ by some 145 to 150°.[71] This was particularly evident at the time of the Falklands conflict when no EORSAT or RORSAT was fully operational at the outbreak of hostilities. Cosmos 1355 was launched four weeks later, well away from the plane of the three previous EORSATs in the series. Cosmos 1365 and Cosmos 1372, which were co-planar and 45 minutes apart, were 150.7° out of plane with Cosmos 1355. Presumably the Falklands crisis influenced the choice of orbits for these satellites and this was taken into account at the launch of Cosmos 1355.

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[69] Pravda, Moscow, Jan. 8, 1983, 2nd ed., p. 2.
[70] Schemann, S. New York Times, Jan. 16, 1983. p. 13.
[71] Johnson, N. L. Spacecraft and Rockets, 1982. p. 113-117.

TABLE 1.—COSMOS RADAR OCEAN RECONNAISSANCE SATELLITES RORSATS: 1967–1982

Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period	Raised	Life
198 67–127A	12/27/67	270	249	65.1	89.7	12/28/67	1
		952	894	65.2	103.4		
209 68–23A	3/22/68	343	183	65.0	89.7	3/23/68	2
		944	871	65.3	103.1		
367 70–79A	10/3/70	264	246	65.1	89.6	10/3/70	[1] 1
		1024	922	65.3	104.5		
402 71–25A	4/1/71	274	247	65.0	89.7	4/1/71	1
		1036	948	65.0	104.9		
469 71–117A	12/25/71	262	249	64.9	89.6	1/3/72	9
		1023	941	64.5	104.7		
516 72–66A	8/21/72	263	251	65.0	89.6	9/22/72	32
		1030	920	64.8	104.6		
626 73–108A	12/27/73	259	257	65.0	89.7	2/9/73	45
		990	910	64.9	104.0		
651 74–29A	5/15/74	264	250	65.0	89.6	7/25/74	71
		954	892	65.0	103.5		
654 74–32A	5/17/74	265	248	65.0	89.6	7/30/74	74
		1024	913	65.0	104.4		
723 75–24A	2/4/75	266	249	65.0	89.6	5/15/75	43
		952	917	64.7	103.7		
724 75–25A	4/7/75	266	248	65.0	89.6	6/10/75	64
		937	869	65.5	103.4		
785 75–116A	12/12/75	261	251	65.0	89.6	12/12/75	<1
		1023	898	65.1	104.3		
860 76–103A	10/17/76	265	252	65.0	89.7	11/10/76	24
		1008	919	64.7	104.3		
861 76–104A	10/21/76	265	251	65.0	89.7	12/20/76	60
		1005	921	64.9	104.3		
952 77–88A	9/16/77	265	251	65.0	89.7	10/7/77	21
		998	910	64.9	104.1		
954 77–90A	9/18/77	265	251	65.0	89.7	Decayed	42
1176 80–34A	4/29/80	266	250	65.0	89.7	9/10/80	134
		966	870	64.8	103.4		
1249 81–21A	3/5/81	265	252	65.0	89.7	6/18/81	105
		985	898	65.0	103.9		
1266 81–37A	4/21/81	268	249	65.0	89.7	4/28/81	8
		965	891	64.8	103.6		
1299 81–81A	8/24/81	267	248	65.0	89.7	9/5/81	12
		984	910	65.1	104.0		
1365 82–43A	5/14/82	264	252	65.0	89.7	9/26/82	135
		977	885	65.1	103.7		
1372 82–52A	6/1/82	270	246	65.0	89.7	8/10/82	70
		981	908	64.9	104.0		
1402 82–84A	8/30/82	265	251	65.0	89.7	Decayed	120
1412 82–99A	10/2/82	266	251	65.0	89.7	11/10/82	39
		983	909	64.8	104.0		

[1] The initial orbit for Cosmos 367 is that given for the platform, 70–79C in the RAE table.

Notes:
1. All satellites were launched from Tyuratam by the F–1m.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to raising to the "safe" orbit in integer days.
3. Orbital data in the second line of each entry refers to the "safe" orbit.
4. Orbital data, which may differ from that given in the Master Log, has been taken from The R.A.E. Table of Earth Satellites 1957–1982, Macmillan, London, 1983.
5. Lifetimes and dates of raising to the "safe" orbit which differ from those given by the R.A.E. are the results of independent calculations.
6. Table prepared for the Congressional Research Service by G.E. Perry.

Cosmos 1405, the third EORSAT of 1982, exhibited a 141° plane separation from the two RORSATs in operation at the time, but led these satellites rather than trailing them like Cosmos 1355. Cosmos 1405 was time-phased with Cosmos 1355 and this was the first occa-

sion on which a pair of EORSATs and a pair of RORSATs operated simultaneously.

EORSATs continued to be launched through 1983 despite the Cosmos 1402 incident. Cosmos 1461 and Cosmos 1507 were time-phased 6° out of plane with each other, thereby sharing the same unique set of ground tracks. There was speculation that Cosmos 1507 was launched to observe U.S naval activity in the Caribbean at the time of the invasion of Grenada but, at that time, also, U.S. naval vessels were assembling in the Middle East following an Iranian threat to blockade the Straits of Hormuz.

Other ELINT Satellites

The Soviet Union operated a constellation of heavy ELINT satellites based on the early Meteor design and launched by the A-1 from Plesetsk beginning in 1970. With periods of around 97.7 minutes in near-circular orbits at 81.2° inclination, they were initially considered by some analysts to be Meteor failures. As time went by and a constellation with 60° plane-separation was established, providing global coverage with regular replacements and from which no scientific results were ever published, it became clear that they were performing some military role.

The precise plane-spacing of the constellation began to degrade in 1980 and their role was assumed by a newer class of satellite, based on earlier Cosmos satellites with announced oceanographic missions. These satellites are launched by the F-2 into 82.5° inclinations, again with periods close to 97.7 minutes.

An earlier sub-set of Cosmos satellites suffered severely from the effect of atmospheric drag at the time of the last solar maximum. Of smaller mass and launched by the intermediate C-1 into orbits with 95 minute periods at 74° inclination, these had provided a constellation of four satellites with 45° plane-separations since the end of the 1960s. During 1980 and 1981, 28 of these satellites decayed in the Earth's atmosphere and at the beginning of 1982 only two, which have since decayed, remained in orbit. This constellation was not re-established.

EARLY WARNING OF MISSILE AND SPACE LAUNCHES

As stated above, the Soviets lacked the capability to launch spacecraft into geosynchronous equatorial orbits until they had developed the D-1e, or Proton, launch vehicle. Instead they used semi-synchronous orbits of high eccentricity, inclined at 65° to the equator, with a long dwell time near apogee in the northern hemisphere, for the Molniya communications satellites operating within the Orbita system.

Cosmos 41, Cosmos 174 and Cosmos 260 may be considered as tests or Molniya replacement failures, but Cosmos 520, in 1972, and later Cosmos satellites with similar orbital parameters, did not fall into the well-defined Molniya groupings. Furthermore, their arguments of perigee, rather than lying between 280° and 288° as for the Molniyas, were all close to 315°.

The relocation of perigee produced broader northern hemisphere ground-track loops near apogee than those of the Molniyas and the ascending node was shifted from 115° to 90°W. In this new position

the satellites could perform an early warning role for a considerable part of each orbit, able simultaneously to view the ICBM sites in the mid-western United States and communicate directly with the Soviet Union.

By 1980, a system of four satellites with orbital planes spaced at 80° was quasi-operational. The reason for the adoption of an 80° orbital plane spacing remained obscure until the launch of Cosmos 1247 in February 1981, when it was placed 40° away from the plane occupied by Cosmos 1191. The constellation of nine planes at 40° spacing was completed with the launch of Cosmos 1367 in 1982. Table 2 shows the development of the constellation from the end of 1980 through 1983.

TABLE 2.—ESTABLISHMENT OF THE FULL CONSTELLATION OF COSMOS EARLY WARNING SATELLITES: 1981–1983

	1	2	3	4	5	6	7	8	9
1	1217		1191			1223		1172	
1				1247					
9					1261				
8		1278							
1					(1285)				
							1317		
1				1341					
9								1348	
8									1367
2						1382			
	1409								
1			1456						
9					(1481)				
8				1518					

Notes:
1. Orbital planes are separated by 40° in right ascension of the ascending node.
2. Cosmos numbers immediately below the double ruling at the head of the table indicate the operational status as of Dec. 31, 1980. During the first quarter of 1981 the ascending nodes of these four satellites were re-positioned some 40° eastward to coincide with that of Cosmos 1247.
3. Cosmos 1261 disintegrated within a month of launch.
4. The ground-tracks of Cosmos 1285 and 1481 were never stabilized.
5. Table prepared for the Congressional Research Service by G.E. Perry.

The launch of Cosmos 1247 also saw the start of a complex series of maneuvers aimed at re-stabilizing all operational satellites with their ascending nodes located close to 55°W. The relocation permitted surveillance of the Atlantic and Pacific Oceans for possible submarine-launched ballistic missiles. The new ground-track is less suitable for performing the early warning role and 24-hour coverage is only possible by communication with a station in the eastern Soviet Union while viewing the mid-western United States and by using a larger number of satellites.

Locating the ascending node near 55°W forfeits the gravitational stability of orbits with ascending nodes close to 110°W. Station-keeping is effected by periodic burns of the orbital correction motor and this may account for the relatively short time which once elapsed before replacement satellites were launched.

These functions are usually considered together under the collective term C-cubed (C^3) or, with the addition of intelligence, as C-cubed I (C^3I).

Semi-Synchronous Satellites

It is generally believed that the Molniya 1 communications satellites described above primarily serve governmental and military needs.[72] Early in 1976, the 32nd Molniya 1 was placed into an orbital plane exactly midway between two of the four standard Molniya planes. Three more launches that year completed a set of four Molniya 1 satellites positioned midway between the standard locations. It was suggested that Molniya ls had assumed a wholly military role, but no sooner had this been published than four new Molniya ls were placed into the original positions. Stephen Birkill showed that the four inter-group Molniyas operated only on the Asian loop, transmitting a digital fsk signal in what was presumed to be a military mode, whereas the other four and their accompanying Molniya 3s carried domestic traffic on both Asian and North American loops of their orbits.[73]

Geosynchronous Satellites

As noted earlier, IFRB notices have provided details of frequencies and locations for Gals (Tack) which appears to be the name of transponders hosted onboard Raduga satellites. Uplink between 7.9 and 8.4 GHz and downlink between 7.25 and 7.75 GHz are in bands officially allocated for Government service, but internationally recognized as military communications bands.

Tactical and Theater Communications

Since 1970 the Soviet Union has regularly launched groups of eight satellites with periods close to 115 minutes at 74° inclination using a single C–1 launch vehicle from Plesetsk. Although the orbital planes drift relative to each other due to differences in the orbital periods, new launches are invariably made into the same orbital plane as that employed initially. A reasonable explanation for this has yet to be advanced. It is believed that a constellation of 24 such satellites forms the operational segment of a real-time tactical communications system within a given theater of operations of a military store-dump system, a view strengthened by Department of Defense (DOD) testimony before Congress that such systems exist beyond the more open Molniya systems.

Between 1970 and 1980 there were 26 such octuple launches at an average rate of two or three annually, with single launches in 1970, and 1977, three launches in each of 1973, 1975 and 1980, and a record four launches in 1978.

There were three octuple launches in 1981, but the third deployed its payloads, Cosmos 1320–1327, into higher than nominal orbits characteristic of a small timing error in the ejection se-

[72] Johnson, N. L. op. cit., p. 59.
[73] Soviet Space Programs: 1976–80, Pt. 3, p. 1086.

quence.[74] There were two octuple launches in each of 1982 and 1983.

Covert Store-Dump

Another sub-set of Cosmos satellites in near-circular orbits at 74° inclination, but with 100.8 minute periods, operates as a three-satellite system with orbital planes spaced at 120°. These are thought to perform clandestine store-dump missions in a COMINT (communications intelligence) role. (In April 1977, an Iranian was arrested by the Shah's police for allegedly receiving coded KGB communications, via a satellite, displaying the message on the LED output of a small pocket electronic calculator.) [75]

Between their introduction in 1970 and 1980 there were 22 such launches with single launches in 1970, 1973, 1974 and 1980 and three launches in each of 1976, 1978 and 1979. Satellites in this system are replaced on average once every 14 months.

The nine missions launched in the years 1981 through 1983 are displayed in table 3. The first of these, Cosmos 1269, was replaced by Cosmos 1302 after a period of less than three months and there was a third launch into that same plane before launches into either of the other two planes. Interpretation of this as due to the rapid failure of the earlier satellites in the plane should be adopted with caution. As will be reported in chapter 4, it has been discovered that this sub-set of satellites employs two discreet frequencies and more than one satellite can be operational in a particular plane at a given time.

Table 3 shows that the first launch of 1983, Cosmos 1452, was not placed in precisely the same plane as Cosmos 1371. Cosmos 1503, the last of the 1983 launches, was also displaced from the standard planes. The repositioning of the planes was completed in 1984 and the original planes were phased out as their last satellites reached the ends of their operational lives.

TABLE 3.—ORBITAL PLANE LOCATIONS OF COSMOS SATELLITES FOR COVERT STORE-DUMP COMMUNICATIONS: 1981–1983

	1	1'	2	2'	3	3'
	1100		1190		1140	
1981	1269					
	1302					
1982	1331					
			1354			
					1371	
	1420					
1983						1452
			1486			
				1503		

Notes:
1. Orbital planes are separated by 120° in right ascension of the ascending node.
2. Cosmos numbers immediately below the double ruling at the head of the table indicate the operational status as of Dec. 31, 1980.
3. Commencing in 1983 with Cosmos 1452 the orbital planes of the constellation were displaced by some 10° from their original locations. The repositioning was completed by Cosmos 1538 in 1984.
4. Table prepared for the Congressional Research Service by G.E. Perry.

[74] Johnson, N. L. Journal of the British Interplanetary Society, 1982. p. 59-66.
[75] Moss, R. Sunday Telegraph, London, Nov. 5, 1978. p. 21.

NAVIGATION

The development of three military navigation systems within the Cosmos program was described in the space applications part of this chapter. As noted there, each satellite is allocated an identity number. Military Cosmos navigation satellites in the third operational system take identities 1 through 9. Initially, identity numbers from 1–6 were allocated to satellites as they were launched, with the satellite which had been replaced taking identity 7 or 8 for some time afterwards. (Cosmos 1464 was observed to have identity number 9 after replacement.) Today, identity numbers are exclusive to the orbital planes in the correct numerical sequence. These satellites employ transmission frequencies which are unique to specific planes and are at 30 kHz intervals from the common 150.00 MHz frequency of the civil navigation satellites. Satellites in planes 1 and 4 transmit on 149.97 MHz. The satellite in plane 2 transmits on 149.91 MHz. Satellites in planes 3 and 6 transmit on 149.94 MHz and the satellite in plane 5 transmits on 150.03 MHz. Almanacs are updated on a weekly basis and, since February 1987, are referenced to the first ascending node of the day by Standard Moscow Time.[76]

Six satellites in near-polar orbits with plane-spacings of 30° provide global coverage so that a ship's captain need never wait long to obtain a positional fix to an accuracy of better than 200 meters. The military satellites are replaced more frequently than those in the civil system suggesting that military satellites operate to more stringent criteria.

Cosmos 1275, in plane 6, disintegrated after 50 days in orbit. The cause of the breakup remains unexplained in the West and fragmentation due to collision with another object cannot be ruled out.[77] Cosmos 1333 experienced a partial failure early in June 1983. This is discussed in detail in chapter 4. Cosmos 1380, launched on June 18, 1983, would appear to have been an attempt to replace the 18 months-old Cosmos 1225, but it suffered a second-stage malfunction leaving it in a highly elliptical orbit with low perigee from which it decayed after nine days.

In the same way that U.S. GPS Navstar satellites employ a P-code for military use, in addition to the lower precision CA-code, one might expect the GLONASS satellites likewise to have a dual purpose. This is discussed further in the annex to chapter 3.

MINOR MISSIONS

The term "minor military" was coined by the late Dr. Charles Sheldon to embrace those Cosmos satellites for which a more obvious role is not immediately apparent. Although no sustained constellations can be detected within the members of this class, this may be due, in some instances, to changing rates of precession of right ascension of ascending nodes as the lower orbits decay.

From 1964 through 1966 all B–1 minor military flights originated from Kapustin Yar at inclinations between 48.4° and 49°. Following the introduction of the B–1 at Plesetsk in March 1967, only one or

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[76] Daly, P. and G. E. Perry. Space Communication and Broadcasting, 1987. p. 379–384.
[77] Johnson, N. L. Soviet Space Programs 1980–1985. op. cit., p. 76–77.

two flights per year came out of Kapustin Yar, the last being in 1972. The majority of flights had periods close to 92 minutes but some had higher periods around 100 minutes and, later, 109 minutes All perigee heights were below 300 km.

The first B-1 flight from Plesetsk was Cosmos 148 with an inclination of 71° and a period of 91.3 minutes. Many more such flights followed together with another series in a higher orbit with periods close to 95.5 minutes. For the even higher period around 102 minutes an 81.9° inclination was employed. The final B-1 flight in the minor military category was Cosmos 919 in June 1977.

The first flight out of Plesetsk to match the 109 minute period of the highest flights from Kapustin Yar required the intermediate C-1 launch vehicle at an inclination of 83°. This was Cosmos 660 in June 1974. Cosmos 1179 in 1980 had a period of 103.5 minutes more nearly like the old 102 minute B-1 flights. Flights at 65.8 and 74° with 95 minute periods also appeared. C-1 flights at 50.7° inclination with 93.4 minute periods were made from Kapustin Yar starting in 1978.

Classification by orbital inclination reveals that four different inclinations are currently employed; 50.7° from Kapustin Yar, and 65.8°, 74.Oo and 82.9° from Plesetsk. Classification by orbital period and eccentricity reveals other groupings as shown in table 4.

TABLE 4.—C-1 LAUNCHED MINOR MILITARY MISSIONS 1981-1983

Payload name	Launch date	Site	Apogee	Perigee	Inclination	Orbital period
Cosmos 1418	10/21/82	KY	414	371	50.7	92.4
Cosmos 1351	4/21/82	KY	546	349	50.7	93.5
Cosmos 1397	7/29/82	KY	541	345	50.7	93.4
Cosmos 1465	5/26/83	KY	543	349	50.7	93.5
Cosmos 1494	8/31/83	KY	551	345	50.7	93.5
Cosmos 1502	10/5/83	PL	411	367	65.8	92.3
Cosmos 1310	9/23/81	PL	517	476	65.8	94.6
Cosmos 1427	12/29/82	PL	496	448	65.8	94.0
Cosmos 1450	4/06/83	PL	511	471	65.9	94.4
Cosmos 1335	1/29/82	PL	514	479	74.1	94.6
Cosmos 1453	4/19/83	PL	515	470	74.0	94.5
Cosmos 1311	9/28/81	PL	516	465	83.0	94.4
Cosmos 1501	9/30/83	PL	513	467	82.9	94.4
Cosmos 1463	5/19/83	PL	1550	300	82.9	103.5
Cosmos 1238	1/16/81	PL	1957	403	83.0	109.0
Cosmos 1263	4/9/81	PL	1968	396	83.0	109.0
Cosmos 1508	11/11/83	PL	1964	398	82.9	109.0

Notes:
1. KY = Kapustin Yar, PL = Plesetsk.
2. Apogee and perigee heights are given in kilometers, orbital inclination in degrees, and orbital period in minutes.
3. Cosmos 1310, 1335, 1351, 1397, 1418, 1463, 1465 and 1501 have decayed.
4. Table prepared for the Congressional Research Service by G.E. Perry.

Cosmos satellites with 65.8° inclinations and periods less than 95 minutes appear, at first sight, to be ASAT test-related, but evidence does not support this. Some, which shed fragments at irregular and somewhat lengthy intervals, are thought to simulate MIRV attacks and provide practice for ground units whose duty it is to detect and/or engage such objects. Others may be used for radar

calibration. It was reported that Cosmos 1311, in 1981, was used to calibrate ABM development programs at Sary Shagan, but no evidence was offered to support this claim.[78]

A book about the Soviet Army suggests that satellites are used to verify compliance with instructions to de-activate certain radars and radio transmitters to prevent "American spy-satellites" from obtaining intelligence over the Soviet Union.[79] It goes on to suggest that dedicated radars and radio transmissions are activated at these times to provide disinformation. This example is cited, not because of any implicit belief in its veracity, but to offer another possibility for a "minor military" mission.

SPACE WEAPONS

Fractional Orbital Bombardment System (FOBS)

From 1967 to 1971, the Soviets conducted a series of flights related to development of a Fractional Orbital Bombardment System (FOBS). The theory behind FOBS was to send ballistic missiles the long way around the globe, thus avoiding the BMEWS (Ballistic Missile Early Warning System) stations constructed in Alaska, Greenland and England to detect missiles launched from the Soviet Union against the United States, Canada, and parts of Western Europe.

The first hint that such a system was in development came in the military parade through Red Square in May 1965 which included a new, very large three-stage liquid fueled ICBM, code-named Scrag by NATO. It was described by the Soviet radio announcer as having as its main property the "ability to hit enemy objectives literally *from any direction*" making them virtually invulnerable to anti-missile defense means.[80] (emphasis added) The corresponding parade in November that same year included the same missiles, and the description spoke of them being able "to inflict sudden blows on an aggressor on the *first* or any orbit round the Earth." [81] (emphasis added)

FOBS tests began in 1967 using the F-class launch vehicles. The launches were promptly announced and Cosmos designations given, but were distinctive in that the announced orbital elements omitted the orbital period. During 1967 alone there were nine such flights. The public explanation was given on November 3, by the U.S. Secretary of Defense, who tagged them as probable FOBS flights. Following the testing phase of nine flights in 1967, there were two flights in 1968, one in 1969, two more in 1970 and the program terminated with the single 1971 flight, on August 8, of Cosmos 443.

The fractional orbit of every one of the 15 flights from 1967 until 1971, when they were terminated, did not once cross the continental territory of the United States. The ground-track at the 49° inclination out of Tyuratam passed eastward across Siberia, down through the central Pacific, across the lower part of South America, up the South Atlantic and across Africa and the Mediterrane-

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[78] Defense Daily, Oct. 29, 1981.. p. 284.
[79] Suvarov, V. Inside the Soviet Army. Macmillan, New York, 1982. p. 106-107.
[80] Moscow Radio, May 9, 1965.
[81] Ibid., Nov. 7, 1965.

an to impact, after retro-fire, on Soviet territory, not far from the launch site.

The termination of the FOBS program left Western analysts in doubt as to whether the program had been so successful that the Soviets did not consider further tests to be necessary, or so unsuccessful that they had decided to scrap the system. The only clue in the open literature as to the status of the system is the fact that the never-ratified SALT II agreement calls for the dismantlement of 12 of the 18 launchers for fractional orbital missiles at Tyuratam, and the remaining six "may be converted to launchers for test missiles undergoing modernization." (Second Common Understanding to Paragraph 2(c)).

Antisatellite Tests (ASATs)

The Soviets have developed a "co-orbital" antisatellite (ASAT) system in which an interceptor satellite goes into a close co-orbit with a target satellite. The interceptor then explodes, and in an operational scenario, the resulting shrapnel would destroy the target. The U.S. Department of Defense states that this system, tested between 1968 and 1982, is operational.

Soviet ASAT tests have been conducted in three different periods of time: 1968–1971, 1976–1978, and 1980–1982. Tests from 1968 to 1970 involved launches of the targets and interceptors using the F–1m launch vehicles from Tyuratam, but in 1971, the Soviets began launching the targets from Plesetsk using the C–1. Interceptors continued to be launched from Tyuratam, necessitating a small plane-change from 65.lo to 65.8° of the targets. In addition to demonstrating a co-orbiting capability, tests were carried out on targets operating at heights characteristic of navigation and photographic reconnaissance satellites.

The hiatus in testing from 1971 to 1976 may have been connected with SALT I, and Western analysts have speculated resumption of testing may have been meant as a warning to the Peoples Republic of China, which in 1975 launched what is considered a military reconnaissance satellite in the West.

The 1976–78 tests involved a new development in which the interceptor disappeared from orbit on the day of launch in the so-called "pop-up" type of interception. No tests occurred from 1978 to 1980 while the United States and Soviet Union were engaged in ASAT limitation talks (no agreement resulted from the negotiations, which ended after the Soviets invaded Afghanistan in 1979).

The resumption of testing in 1980 involved the launch of Cosmos 1174 which made a two-orbit interception of Cosmos 1171 in a 1000–km orbit, typically used for navigation satellites. In 1981, Cosmos 1241 was intercepted by Cosmos 1243 and Cosmos 1258. There were reports that a Pentagon source had claimed that, in the latter instance, the target satellite had been successfuily "knocked out", the interceptor exploding near to it in what has come to be called a "hot metal", or kinetic energy, kill as opposed to the use of a directed-energy beam weapon. No fragments were catalogued by NORAD, however, calling into question that assertion. Later it was reported that Cosmos 1243, using a new unjammable optical guidance system, was judged to have failed in its mis-

sion but that Cosmos 1258, with the older onboard radar guidance, had probably been successful.

The most recent test of the Soviet co-orbital ASAT system took place on June 18, 1982, and appears to have been a carbon copy of the 1981 tests with Cosmos 1379 making a pass close to Cosmos 1375 before being de-orbited. Cosmos 1375 continued in orbit after being intercepted and suddenly disintegrated, for no apparent reason, on October 21, 1985.

Judging the success of the Soviet ASAT tests is difficult. Based on unclassified sources, table 5 lists Soviet ASAT tests and whether they were successes or not, showing 9 successes and 11 failures for the program overall. All of the successes and five of the failures apparently used a radar homing sensor, giving that version a 64 percent success rate. All of the tests using an optical sensor failed.

TABLE 5.—THE SOVIET ANTISATELLITE (ASAT) PROGRAM: 1968–1982

	Probable target satellite						Interceptor Satellite							
Test	Cosmos number	Launch date	Apogee	Perigee	Inclination	Orbital period	Cosmos number	Launch date	Apogee	Perigee	Inclination	Orbital period	Remarks	Result
1	248	10/19/68	543	475	62.3	94.8	E249	10/20/68	2157	493	62.4	112.1	Came within 1 km of C.248 after a 2-orbit chase	F
2	.....						E252	11/01/68	2149	531	62.3	112.5	Came within 1 km of C.248 after a 2-orbit chase	S
3	373	10/20/70	544	472	62.9	94.8	E374	10/23/70	2141	521	63.0	112.3	Came near C.373 after a 2-orbit chase	F
4	.....						E375	10/30/70	2098	524	62.8	111.8	Came within 1 km of C.373 after a 2-orbit chase	S
5	394	02/09/71	614	572	65.8	86.5	E397	02/18/71	2202	574	65.7	113.5	Came within 1 km of C.394 after a 2-orbit chase	S
6	400	03/18/71	1006	983	65.8	105.0	D404	04/04/71	1010	802	65.7	103.1	Came within 1 km of C.400 after a 2-orbit chase	S
7	459	11/29/71	260	224	65.8	89.3	E462	12/03/71	1800	230	65.8	105.1	Came within 1 km of C.459 after a 1-orbit chase	S
8	803	02/12/76	618	554	65.9	96.4	D804	02/16/76	615	556	65.9	96.4	Came near C.803 after a 1-orbit chase	F
9	.....						D814	04/13/76	480	118	65.1	90.5	Came within 1 km of C.803 after a 1-orbit chase	S
10	839	07/08/76	2098	984	65.9	116.7	843	07/21/76	346	132	65.1	89.3	Failed to attain intercept orbit	F
11	**880**	**12/09/76**	**617**	**560**	**65.9**	**96.4**	**E886**	**12/27/76**	**1265**	**531**	**65.9**	**103.0**	**Came within 1 km of C.880 after a 2-orbit chase**	F
12	909	05/19/77	2109	990	65.9	117.1	D910	05/23/77	1775?	[−300?]	65.9?	99.6?	Failed to complete 1 orbit	F
13	.....						D918	06/17/77	243	128	65.1	88.2	May have come within 1 km of C.909 before	S
14	959	10/21/78	850	146	65.9	94.6	D961	10/26/77	1421	269	66.4	101.8	Probably came within 1 km of C.959 after a 2-orbit chase	S
15	**967**	**12/13/77**	**1005**	**963**	**65.8**	**104.8**	**E970**	**12/21/77**	**1141**	**949**	**65.9**	**106.4**	**Came near C.967 after a 2-orbit chase**	F
16	.....						**D1009**	**05/19/78**	**1364**	**966**	**65.9**	**108.6**	**May have come within 1 km of C.967 after a 2-orbit chase**	F
17	**1171**	**04/03/80**	**1033**	**947**	**65.8**	**104.9**	**D1174**	**04/18/80**	**1025**	**362**	**65.8**	**98.6**	**Came near C.1171 but may have failed; approached C.1171 again on the following day**	F

TABLE 5.—THE SOVIET ANTISATELLITE (ASAT) PROGRAM: 1968–1982—Continued

	Probable target satellite						Interceptor Satellite							
Test	Cosmos number	Launch date	Apogee	Perigee	Inclination	Orbital period	Cosmos number	Launch date	Apogee	Perigee	Inclination	Orbital period	Remarks	Result
18	**1241**	**01/21/81**	**1011**	**977**	**65.8**	**105.0**	**D1243**	**02/02/81**	**1017**	**297**	**65.9**	**97.9**	**Came near C.1241 after a 2-orbit chase but thought to have failed**	**F**
19	.....						D1258	03/14/81	1026	303	65.8	498.0	Came near C.1241 after a 2-orbit chase	S
20	**1375**	**06/06/82**	**1011**	**981**	**65.8**	**105.0**	**D1379**	**06/18/82**	**1021**	**539**	**65.8**	**100.4**	**Came near C.1375 after a 2-orbit chase but thought to have failed**	**F**

Notes:
1. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
2. Orbital data, which may differ from that given in the Master Log, has been taken from the RAE Table of Earth Satellites 1957–1986, Macmillan, London, 1987.
3. Entries in bold type indicate satellites believed to have used an infra-red optical sensor. Other interceptors are believed to have used radar sensors. None of the optical sensor tests are believed to have been successful.
4. The letter E preceeding the Cosmos number of an interceptor indicates that the spacecraft exploded after conducting the test. A letter D indicates that the spacecraft was de-orbited following the test.
5. Al interceptors were launched by the F–1m from Tyuratam.
6. Cosmos 248 and Cosmos 373, the first two target satellites, were launched by the F–1m from Tyuratam. All subsequent target satellites were launched by the C–1 from Plesetsk.
7. No target satellite was re-used following a successful interception.
8. Table prepared for the Congressional Research Service by G.E. Perry.

CHAPTER 2—SPACE SCIENCE

Between 1984 and 1987, the Soviet Union launched two more probes to Venus, VEGA 1 and 2, which then went on to encounter Comet Halley. Two more earth-orbiting spacecraft were launched for solar-terrestrial studies of the magnetosphere and ionosphere, Prognoz 10-Interkosmos and Cosmos 1809. No probes were launched to Mars, although two Phobos spacecraft, to study Mars' moon by that name, were launched in the summer of 1988 and will be included here for completeness even though the launches occurred beyond the time frame of this report.

The VEGA probes not only provided a wealth of information about Comet Halley and Venus, but also gave the Soviets their first major public relations coup in solar system exploration activities. Perhaps the most interesting aspect of the total Soviet space science program, however, was the movement toward more international participation in these projects, and the increasingly open discussion of Soviet proposals for the future.

This chapter reviews Soviet space science activities other than those conducted as part of, or in support of, the Soviet piloted space program, since they have already been covered in Part 1 of this study.[1] Thus, missions carrying animals (the biosatellite missions) and experiments conducted on Soviet space stations are not included.

Analyses of Soviet Space Science Program

In January 1986, a group of American scientists convened under the auspices of the Foreign Applied Sciences Assessment Center (FASAC), published an analysis of Soviet space science activities.[2] The group made several observations about the scientific quality of Soviet space science efforts and the availability of information about these activities in the West. While some of these observations might have changed in the intervening three years, they nevertheless provide a valuable assessment of Soviet space science through the end of 1985.

In solar-terrestrial research, the group noted that the Soviets successively build upon previous programs, starting with rather simple instrumentation for cosmic ray research which was upgraded and augmented considerably over the years by sophisticated plasma instrumentation to provide data on the space plasma environment. The FASAC group concluded that the driving force for

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[1] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Soviet Space Programs 1981–1987: Part 1. Prepared by the Congressional Research Service. Washington, U.S. Govt. Print. Off., 1988.

[2] Lanzerotti, L. J. et al. Soviet Space Science Research. Foreign Applied Sciences Assessment Center. McLean, VA., Science Applications International Corp., Jan. 31, 1986. FASAC-TAR-3060. Hereinafter "The FASAC report."

most of the Soviet solar-terrestrial research is obtaining data relative to human habitation in space. As far as results are concerned, the scientists stated that "the United States has been the leader and principal contributor to advances in solar-terrestrial physics and, with a few important exceptions, has dominated the field." They stated that the Soviet program was "impressive in terms of numbers, not so impressive in terms of scientific yield," and that "research areas seem to be pursued well after the cream of the scientific yield has been skimmed." They listed as the most impressive areas of the Soviet program: solar event forecasting and solar particle research; active experiments in magnetospheric and ionospheric physics; and ionospheric radiophysics.

In the field of planetary exploration, the group concluded that Soviet planetary exploration had arrived at a point where research excellence in the exploration of Venus and research thrusts in the area of comets led those of the United States. They called the Venus exploration program "outstanding" and lauded the Soviets for providing key data for understanding the evolution of the planet and instrumentation that performed "exceptionally well" in the planet's harsh environment.

The Soviets have contributed relatively little in experimental space astronomy and astrophysics, according to the FASAC report, with the possible exception of gamma ray bursts. This is despite Soviet eminence in theoretical work in these areas.

Overall, the FASAC report noted that the Soviet space science program apparently is

> consciously pursued as a scientific enterprise, an activity which proceeds in a systematic fashion, building upon current understanding of a phenomenon or a process to probe more deeply with the next mission into the fundamental underlying . . . processes.

They contrasted this approach with that of the United States and Europe where specific individual missions are the "essence" of the program. They said the reasons for the Soviet approach were unclear, but could be the result of the intrinsic nature of the Soviet science system "where considerable built-in inertia exists." They added, however, that "if the inertia factor has any role to play in the systematics of Soviet space research . . . it has operated largely to the benefit of Soviet space science" allowing "more systematic planning of both space and ground-based experimentation in order to achieve scientific objectives."

The FASAC report noted the problems encountered in the West when trying to gain access to results of Soviet space science programs, especially the fact that it takes much longer for Soviet results to be published, so that Soviet works are not often cited in Western literature. They also observed that Soviet scientists often report orally on results of science missions at international conferences, but many of the projects and results discussed never seem to appear in published Soviet literature. They added that many results ultimately appear in Western journals in articles co-authored by Western scientists.

In the spring of 1988, Dr. Roald Sagdeyev, who headed the Soviet Institute for Space Research (IKI) from 1973 until November 1988,

issued a scathing attack on Soviet science in general. Although it was not specifically aimed at space science, as part of the overall Soviet science effort, it can be assumed that his comments included space science activities, too. Sagdeyev's comments were originally published in the April 28 edition of Izvestiya, and then were adapted for the summer 1988 edition of Issues in Science and Technology, a journal published by the U.S. National Academy of Science. Among the observations, Sagdeyev said:

> Soviet science can be justly proud of its contribution to the discovery of the laser, and Soviet technology exhibited its prowess with the launching of Sputnik and with subsequent space achievements. But such flashes of brilliance are rare. The shortcomings of Soviet science are apparent from the subatomic world of physics to the boundless world of astronomy. Of the dozen fundamental elementary particles discovered by our generation Soviet physics contributed none. Of the hundreds of other subatomic particles and resonances considered derivatives of the main particles, we can claim to have contributed to the discovery of perhaps one or two percent. As astronomy has opened new windows on our understanding of the origin and development of the universe, Soviet scientists have added little of value. In the biological sciences, the enduring influence of Trofim Lysenko's stubborn rejection of mainstream science severely damaged Soviet life science, and the consequences are felt even now.
>
> For too long, Soviet science has hidden its inadequacies behind official panegyrics to its success. In academic and political forums alike, exaggerated claims have been made for the achievements of Soviet science. Science has its own criteria for success, however, and Soviet achievements have not measured up to them.[3]

He went to extol the virtues of international cooperation in science, and as can be seen by projects like VEGA and Phobos, he has made a personal commitment to increasing cooperation in the space science area.

Earth Orbital Science

The following review of Soviet earth-orbital science for the years 1984-1987 might leave the impression that the Soviets have not been very active in this area, since there are only two launches. If the experiments conducted on space stations are taken into account, however, it does show a steady, albeit modest, level of activity that would include operations with the Kvant x-ray astrophysical observatory that docked with the Mir space station in 1987. The reader should consult Part 1 of this report for a discussion of space station science activities for this period of time.

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[3] Sagdeyev, Roald Z. Science and Perestroika: A Long Way to Go. Issues in Science and Technology, Summer 1988. p. 48-49. This article was based on an article he wrote in Izvestiya on Apr. 28, 1988.

Prognoz 10-Interkosmos

Prognoz 10-Interkosmos, the first satellite with a combined designation like this, was launched on April 26, 1985. Its objective was to study the structure of interplanetary and near-earth shock waves arising from the interaction of the solar wind and Earth's magnetosphere. Czechoslovakia contributed some of the experiments on the spacecraft. It was placed into a highly elliptical orbit typical of Prognoz spacecraft, 200,000 by 400 kilometers, with a period of 96 hours 25 minutes and inclination 65 degrees. The shock wave is at a distance of 100–150,000 km; hence the choice of orbit. Czechoslovakia developed a computer to control the spacecraft since its instruments needed to be activated just at the moment when the spacecraft crossed into and out of the shock wave during its orbits.

In describing the need for the spacecraft, Dr. A. Galeev of the Soviet Institute for Space Research[4] explained that the shock wave is very thin and the spacecraft takes literally one second to pass through it. Hence the need for computer control to ensure that the instruments are operating at that precise moment. The spacecraft encountered the shock wave twice on each orbit.[5]

According to Stanislav Fischer, deputy director of the Czechoslovak Academy of Sciences Institute of Astronomy, the project took 8 years to prepare because of technical and organizational problems, noting it was an "unprecedentedly major project in terms of cost, and work investment" comparable to the VEGA project[6] (see below). Soviet scientists referred to this mission as "Inter-Shock."

Cosmos 1809

On December 18, 1986, Cosmos 1809 was launched into a 980 by 960 km orbit, inclined at 82.5 degrees, with a 104.2 minute period. Little information was given about the satellite, other than that it was a cooperative project between the Soviet Union and Poland for ionospheric studies. On February 2, 1988, TASS announced that the spacecraft's mission was complete and data processing had begun. Wave propagation in the upper layers of the atmosphere, effects of ground radio transmitters on the ionosphere, and the nature of electromagnetic interference caused by orbiting spacecraft were areas of study.

Solar System Exploration

Although in recent years considerable concern has been expressed by Western scientists about the breadth and pace of the Soviet solar system exploration program, the years 1983–1987 demonstrated the modest pace at which the Soviet planetary exploration program proceeds. Only two probes were launched, VEGA 1 and 2, for studies of Venus and Comet Halley. As noted earlier, the Phobos probes which were launched in July 1988 will also be in-

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[4] At the end of 1988, Dr. Galeev was elected to the position of Director of the Institute for Space Research, replacing Roald Sagdeyev.

[5] Sotsialisticheskaya Industriya, Apr. 27, 1985, p. 4.

[6] Moscow Domestic Service, 1500 GMT, Apr. 26, 1985.

cluded here, even though the launch occurred outside the purview of this report, for the sake of completeness.

THE VEGA PROGRAM

The name VEGA reflects the dual nature of this program—VE for Venera, GA for the cyrillic spelling of Halley—designating its mission as investigations of Venus and Comet Halley. Not only did the VEGA probes send back a wealth of scientific data about Venus and the comet, but because of the opening of the Soviet space science program to greater Western participation and review, it was a public relations bonanza for the Soviet Union.

The probes were international, including equipment not only from Soviet bloc countries (Czechoslovakia, Hungary, Bulgaria and Poland), but from four Western countries as well: France, West Germany, Austria and the United States (as discussed in more detail below, the U.S. contribution was provided by a university professor working through the West Germans, and was not a direct government-to-government cooperative effort). At the time of the Comet Halley intercept, IKI invited a large group of Western observers to be on hand when the encounters occurred, an unprecedented move for the Soviets. In addition, the Soviets actively participated in an international group that coordinated Comet Halley observations. Called the Inter-Agency Consultative Group (IACG), it was composed of representatives of the Soviet Union, Japan, the European Space Agency, and the United States,

According to the Soviets, their VEGA program cost approximately 100 million rubles.[7]

Event Summary

VEGA 1 was launched on December 15, 1984, and VEGA 2 followed on December 21. Both were launched from Tyuratam using the Proton launch vehicle. The VEGA 1 entry probe was released on June 9, 1985, and entered Venus's atmosphere on June 11. The landing module touched down at 7 degrees 11 minutes north latitude, 177 degrees 48 minutes longitude. The VEGA 2 entry probe was released on June 13 and entered the atmosphere on June 15, the landing module touching down at 6 degrees 27 minutes south latitude, 181 degrees 5 minutes longitude. Both landed on the night side of the planet. The fly-by modules, using a gravity assist from Venus, continued on to intercept Comet Halley on March 6 and March 9, 1986, respectively.

Cooperation with the United States

Four days after the launch of VEGA 1 and one day before VEGA 2's launch, Dr. John Simpson of the University of Chicago announced that he had designed a comet dust analyzer that was aboard each of the spacecraft.[8] Dr. Simpson stated that he had been approached by Dr. Roald Sagdeyev, then director of IKI, about flying the instrument on the VEGA probes after he was unable to have it incorporated on the European Comet Halley spacecraft,

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[7] Soviets to Aid Halley's Comet Observations. Aviation Week and Space Technology, Jan. 2, 1984. p. 20.

[8] University of Chicago News Release, Dec. 20, 1984.

Giotto. Dr. Simpson received approval from the U.S. State Department, Department of Defense, and NASA (which also funded the project) to accept the invitation. He worked through the Max Planck Institute in West Germany since the United States and Soviet Union did not have a formal cooperative space agreement at the time. The device recorded the impact of dust particles, providing data on their mass and density. Other U.S. scientists also were involved with the VEGA project, including Dr. Bradford Smith of the University of Arizona who served as a member of the imaging analysis team, John Hseih, an Arizona physicist who designed the neutral mass spectrometer which was built by the Max Planck Institute, and Andrew Nagy of the University of Michigan who was a member of the plasma physics team, working with Hungarian scientists.[9] A U.S. scientist developed one of the instruments carried on the balloon part of the mission, working with the French.

The participation of the U.S. scientists was not given high visibility by either country prior to the mission because of strained relations. In 1982, President Reagan had chosen not to renew the bilateral space cooperation agreement because of concerns about Soviet activity in Poland. A new agreement was not signed until 1987, so at the time of the VEGA missions, government-to-government level cooperation was almost non-existent.[10] In official statements, the Soviet Union maintained that the United States was not participating in the program.[11]

In addition to the Comet Halley involvement, the United States also was very involved in tracking VEGA 1 and 2, using NASA's Deep Space Network to track the French/Soviet balloons in Venus's atmosphere and to track both spacecraft as they encountered Halley's Comet. The Soviets dealt with this cooperative aspect by mentioning all the countries that were involved in an international network to track the spacecraft (see below), stating that antennas in North and South America were included in the complement, but not specifically saying the United States was involved.

Spacecraft Design

The two VEGA spacecraft, which were identical, are depicted in figures 1 and 2. The spherical object shown on the top in figure 1 is the entry module that housed the balloon and landing module for studies of Venus. The fly-by module, also shown in figure 1 and in more detail in figure 2 was used for the Comet Halley intercept. Figures 3 and 4 shown the trajectory profile of the entry probe and a more detailed view of the lander.[12]

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[9] Wilford, John Noble. U.S. Device Riding Soviet Spacecraft. New York Times, Dec. 21, 1984. p. A1, 23.

[10] Two programs started under the 1977-1982 agreement were allowed to continue despite the lack of the agreement's renewal. These were related to a biosatellite mission and a search and rescue satellite system. Thus, there was a small amount of governmental cooperation for existing projects.

[11] Moscow Television Service in Russian, 1510 GMT, Jan. 12, 1985. Also see: Soviet Denies U.S. Participation in Soviet Halley Mission. Defense Daily, Jan. 6, 1985. p. 39.

[12] The technical characteristics of the VEGA spacecraft and its instruments are described in detail in: Balebanov, V. M. et al., eds. Venus-Halley Mission: Experiment Description and Scientific Objectives of the International Project VEGA (1984-1986). [n.p.] Imprimerie Louis-Jean (Publications Scientifiques et Litteraires), [n.d.] 209 p. Figures 1-4 are based on illustrations appearing in that book.

Figure 1.—The Vega Spacecraft

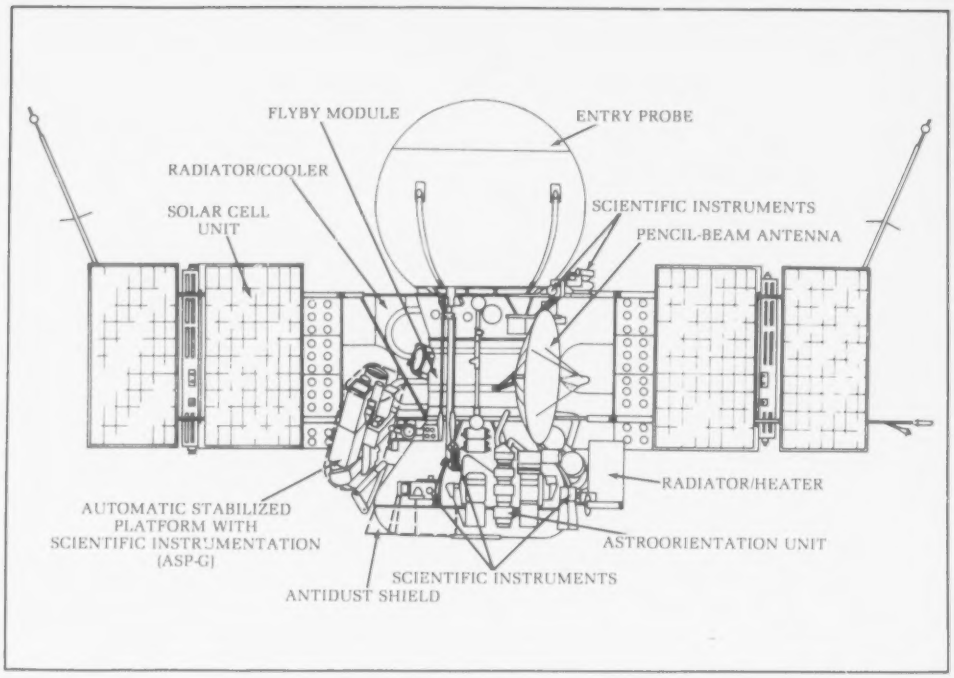


Figure 2.—The Vega Flyby (Comet Intercept) Module

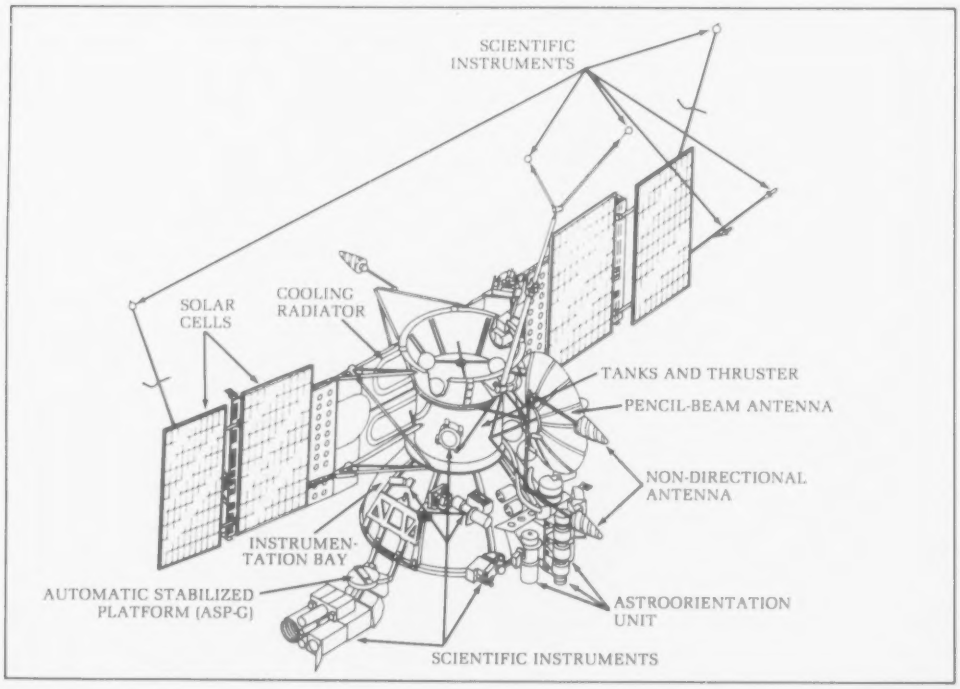


Figure 3.—Trajectory of the Vega Entry Probe AT Venus

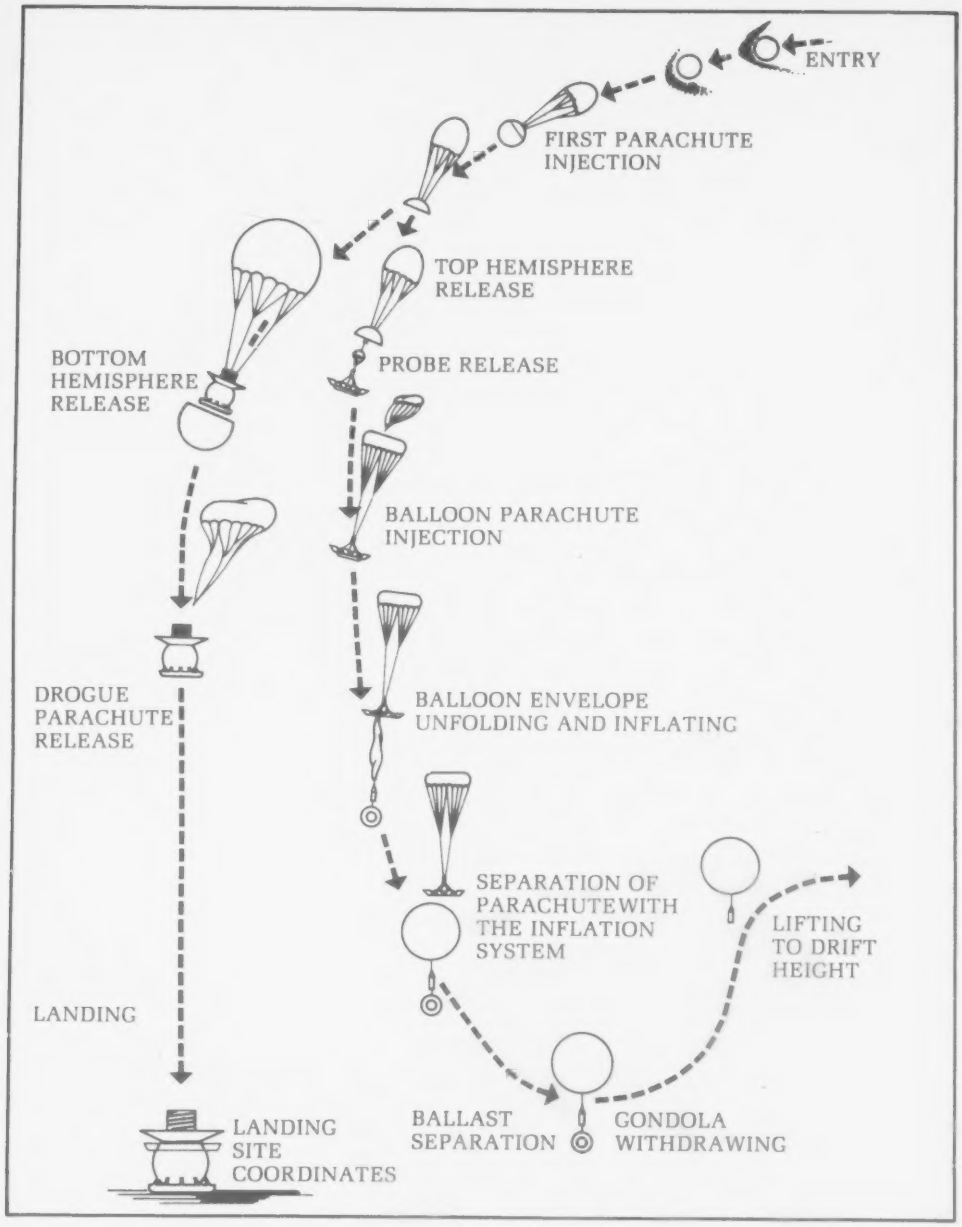
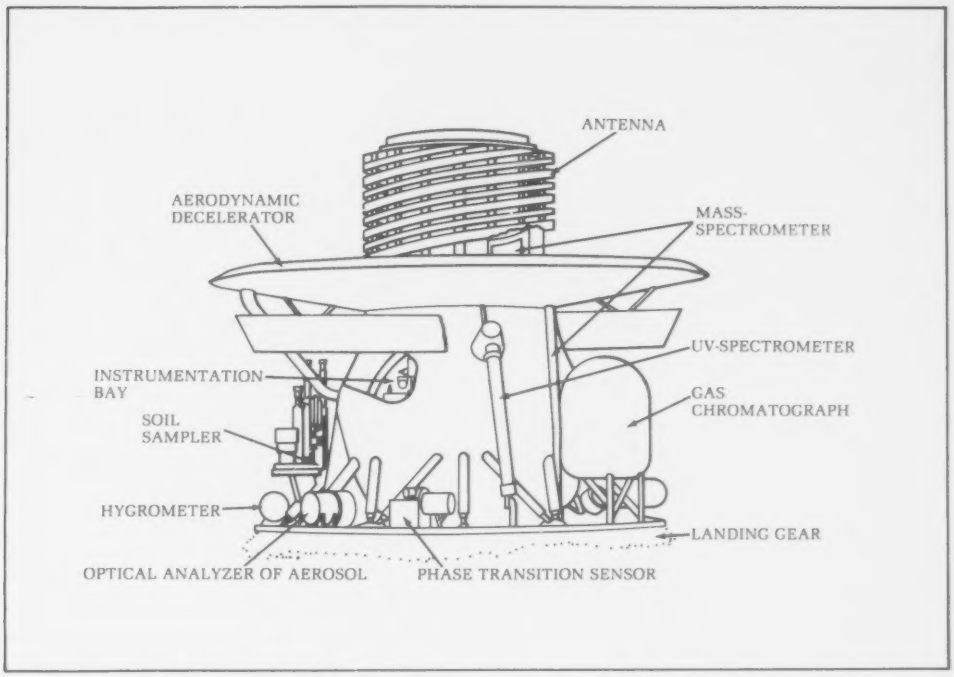


Figure 4.—Vega Lander



The Venus Entry Modules

The VEGA 1 and VEGA 2 entry modules each consisted of a landing module plus one balloon. The balloons were built cooperatively by the French and Soviets. Two-way communications with the probes were made using the 6 Gigahertz (GHz) band, while a different frequency (1.67 Ghz) was used for the balloons.

The Soviets decided to build the VEGA probes in 1980, revising their original plan to launch two probes only to Venus in 1984.[13] The original 1984 mission was to carry the French balloons, and when the Soviets changed the mission to include a Comet Halley encounter, they asked the French to design smaller balloons so the Comet Halley instruments could be accommodated. The French determined that new balloons could not be delivered in time, so the balloon idea was dropped and the French role was renegotiated so that French scientists participated in building instruments for the lander and fly-by modules.[14] Then the Soviets decided to build the balloons themselves using a French design and the instruments they carried were built by the French.[15]

The balloons were built of Teflon and automatically filled with helium at a predetermined altitude (54 kilometers) as they descended towards the surface of Venus. Drop tests were conducted from helicopters and airplanes to ensure that the release mechanism

[13] Soviets Revise 1984 Venera Unmanned Mission Plan to Include 1986 Flyby of Halley's Comet. Aviation Week and Space Technology, Nov. 10, 1980. p. 18-19.
[14] Le Monde, Feb. 12, 1981, p. 4.
[15] Soviet VEGA Launches Set for Dec. 1984. Aerospace Daily, Dec. 21. 1982. p. 269.

worked. Each balloon was 3.4 meters in diameter, supporting a total mass of 21 kilograms (kg) including a 6.9 kg gondola suspended by a 13 meter tether. The balloons used lithium batteries for power, which could last 46–52 hours. Two watt transmitters operating at 1.67 Gigahertz sent back data in 5.5 minute bursts at a rate of 4 bits per second.[16]

The Comet Intercept Fly-By Modules

The fly-by modules that intercepted Comet Halley carried a wide variety of scientific instruments. The module's total mass was 3,500 kg, including fuel. The science platform had a mass of 253 kg, of which experiments accounted for 85 kg.[17] The following experiments were carried:

(1) A two camera television system with an onboard microprocessor, built by the Soviet Union, France, and Hungary. The cameras produced both black and white and color images of the nucleus and central coma region. Focal lengths were 150 mm and 1,200 mm for the two cameras. By using both wide-angle and narrow-angle systems, images of the entire comet, with the coma and the tail, as well as high resolution images of the nucleus, were possible. Spatial resolution of the long focal length camera was 180 meters;

(2) A three-channel spectrometer developed by the Soviet Union, Bulgaria and France which provided data on emissions in the ultraviolet, visible and infrared bands;

(3) An infrared spectrometer built by France with three optical channels, two of which operated in a spectroscope mode, and a third designed to construct an infrared nucleus image;

(4) A dust mass spectrometer built by the Soviet Union and West Germany;

(5) Two dust particle counters built by the Soviets. One was an acoustic type made of metal plates with detectors made from piezoelectric elements on each plate. The other was a plasma detector;

(6) A neutral-gas mass spectrometer built by Hungary, West Germany, and the Soviet Union;

(7) An ion mass spectrometer and electron analyzer package containing five detectors, built by the Soviet Union and Hungary;

(8)A high-energy particle counter built by Hungary, West Germany and the Soviet Union;

(9) Plasma wave analyzers built by Czechoslovakia, France, Poland and the Soviet Union; and

(10) Magnetometers that could measure the magnetic field to an accuracy of 10–6 Gauss built by Austria.[18]

The VEGA 1 module was designed to fly as close as 10,000 kilometers to the nucleus, and VEGA 2 even closer, 3,000 km. Intercept velocity was 80 kilometers per second. It was difficult to construct spacecraft able to withstand an encounter of this magnitude with particles from the comet impacting the spacecraft at such

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[16] Dornheim, Michael A. Soviets' VEGA 2 Balloon, Lander Transmit Data From Venus. Aviation Week and Space Technology, June 24, 1985. p. 23.

[17] Clark, Phillip. The VEGA Missions. Spaceflight, May 1985. p. 219.

[18] Seven Nations to Contribute to Soviet Comet Observations. Aviation Week and Space Technology, July 12, 1982. p. 72; also: Izvestiya, Dec. 16, 1984, p. 2.

high velocity, so the spacecraft had a special "armor" of two and three layers of skin.[19]

Operations and Results

The Balloons

Details on the design of the balloons and analysis of the resulting data were published on March 21, 1986 in Science, a publication of the American Association for the Advancement of Science, from which much of the following material is extracted.[20] The balloons were released on the night side of the planet, then drifted with the clouds towards the Sun.[21] Instruments were designed to make meteorological measurements (including temperature and pressure) as well as the frequency of lightning flashes, the vertical velocity of wind gusts, and the location and density of clouds.

Twenty antennas around the world were used to track the balloons, including six in the Soviet Union whose operation was coordinated by IKI, and fourteen around the world coordinated through the French space agency CNES and including NASA's three Deep Space Network antennas in the United States, Spain and Australia (the other 11 were radio astronomy observatories).[22] By using such a large number of antennas located at great distances from each other, the technique of very long baseline interferometry could be used, providing accuracy of 4 km per hour in the tracking area. Five antennas were used to actually receive telemetry, and they then could direct the other antennas where to look.[23]

Both balloons were deployed at a longitude of 180 degrees near Venus midnight.[24] VEGA 1 entered at 7 degrees north of the equator and VEGA 2 at 7 degrees south. Each was tracked over a distance of 11,500 km, encountering dawn at 33 hours after deployment. The float time of each balloon was estimated at 46 hours and data were received for 22.5 hours from each. Each flew at approximately 54 km altitude. The speed of the balloon's movements, and therefore of Venus' cloud layer, was 200 kilometers an hour (60 meters per second). Descending and ascending currents were recorded at a speed of up to 4 km per hour, buffeting the VEGA 1 balloon by as much as 200–300 meters up and down.[25] VEGA 2 encountered even stronger vertical winds, up to 11 km per hour, when the balloon was over Aphrodite, one of the highest mountainous areas on the planet.[26]

Results from the VEGA data showed that at altitudes from 63 to 48 km, there is an average of 1 milligram of sulfuric acid per cubic meter of atmosphere, and the clouds contains sulphur (some in free

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[19] Sovetskaya Estoniya, Dec. 16, 1984, p. 3.

[20] The Jan. and Feb. 1986 issues of the Soviet "Pisma v Astronomicheskiy Zhurnal" also detailed results from the Venus part of the VEGA mission.

[21] Izvestiya, Nov. 18, 1984, p. 3.

[22] In total, facilities in ten countries were used: Australia, Brazil, Canada, England, West Germany, South Africa, the Soviet Union, Spain, Sweden and the United States.

[23] Dornheim, Michael A. Soviets' VEGA 2 Balloon, Lander Transmit Data from Venus. Aviation Week and Space Technology, June 24, 1985. p. 24.

[24] Sagdeyev, R. Z. et al. The VEGA Venus Balloon Experiment. Science, Mar. 21, 1986. p. 1407.

[25] TASS, 1400 GMT, June 15, 1985.

[26] Weather Balloons at Venus. Science, Mar. 21, 1986, p. 1369.

form), chlorine and phosphorous.[27] The lightning sensors detected no lightning around or beneath them.

The Landing Modules

Not much information has been published about the landing modules, possibly because the instruments they carried were similar to those on Venera 13 and 14 and more attention was focussed on the new experiments conducted with the balloons.[28] It is also possible that some of the experiments failed. The landing modules had instruments for atmospheric measurements during descent, and soil analysis equipment, including a drill. Data from the VEGA 2 landing site showed the soil to be soft and similar to loose andesite-basalt soils on Earth, different from the previous landing sites.[29] The VEGA 1 lander transmitted data for 21 minutes.[30]

The landers carried gamma spectrometers which began operating at an altitude of 25 km. VEGA 1 produced 9 spectra before landing and eight afterwards. VEGA 2 produced 10 before landing and nine after. Results from these instruments reportedly showed that the Venusian rocks were similar to tholeitic basalts and gabborids.[31]

The Encounter with Comet Halley

The VEGA 1 fly-by module passed Venus at a distance of 39,000 km,[32] while VEGA 2 passed the planet at a distance of 24,500 km.[33] Both received gravity assist boosts from Venus to enable them to reach Comet Halley.

On February 12, 1986, the fly-by probes were put into an operational mode and on February 14, the television cameras were targeted on Jupiter as a systems test.[34] The first pictures of Comet Halley were received on March 4 when VEGA 1 was at a distance of 14 million km from the comet (and 171 million km from Earth). Pictures were taken for 90 minutes through various filters and several dozen pictures were returned.[35] Photos of the comet were also obtained on March 5 from a distance of 7 million km, and on March 6, at closest approach, which was 9,000 km from the nucleus, slightly closer than planned. Measurements were made during a three hour period and more than 500 television pictures were returned in total.[36]

VEGA 2 reached its closest point, 8,200 km from the nucleus, on March 9.[37] Either a cosmic ray or a dust particle disabled the microprocessor system monitoring the exposure for the camera, caus-

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[27] Pravda, Nov. 18, 1985, p. 8.

[28] Of 23 articles about the VEGA missions in the Jan. and Feb. 1986 issues of Pisma v Astronomicheckiy Zhurnal, only 1 was on results from the experiments at the landing site.

[29] Trud, June 16, 1985, p. 3.

[30] Dornheim, Michael A. Soviets' VEGA 2 Balloon, Lander Transmit Data From Venus. Aviation Week and Space Technology, June 24, 1985. p. 23.

[31] Pisma v Astronomicheskiy Zhurnal, Feb. 1986, p. 114–119. English abstract in JPRS–USP–86–006, Nov. 12, 1986. JPRS is the Joint Publication Research Service, a series of publications by the Foreign Broadcast Information Service (FBIS). FBIS publications are available from the U.S. Dept. of Commerce National Technical Information Service (NTIS).

[32] TASS, 0813 GMT, June 11, 1985.

[33] TASS, 0725 GMT, June 15 1985.

[34] TASS, 1145 GMT, Feb. 17, 1986.

[35] Leningradskaya Pravda, Mar. 5, 1986, p. 1.

[36] Leningradskaya Pravda, Mar. 7, 1986, p. 11.

[37] Izvestiya, Mar. 10, 1986, p. 1.

ing the images to be somewhat overexposed. A total of about 700 pictures were taken with VEGA 2, however.[38]

Both spacecraft were damaged during the encounter, VEGA 2 receiving more damage for unknown reasons since it approached the comet from its quiet side. Power from the solar panels was reduced by 80 percent on VEGA 2, and 40–45 percent on VEGA 1.[39] Two VEGA 1 experiments and three on VEGA 2 ceased functioning during closest approach, probably because of damage from the dust.[40] The spacecraft first detected gas sublimated from the comet's nucleus at a distance of 35 million km, and the first dust particles were encountered more than 200,000 km out.[41]

Data from VEGA 1 showed the comet's magnetic field to have an intensity as high as 75 nanoteslas. Instruments recorded up to 3,000 dust particles per square decimeter each second at closest approach, and a large quantity of water vapor was detected, as well as the presence of all molecules with a weight of less than 28. Scientists found that 30 tons of water vapor and 5–10 tons of dust evaporate from the surface of the nucleus every second. The shock wave boundary was at 1 million km.[42] Based on the VEGA data, Soviet scientists concluded that the nucleus was irregularly shaped, with a diameter of 14 km and height of 7 km, resembling either a peanut or a potato.[43] Temperature of the surface of the nucleus was deduced to be approximately 100 degrees C, higher than expected.

Both spacecraft survived the encounter with Comet Halley, despite the damage. In January 1987, almost a year after the encounter, the probes were reported to be in heliocentric orbit and regular radio communications sessions were being conducted.[44]

THE PHOBOS PROGRAM

The Soviet interest in publicizing and sharing data from the VEGA mission also prevails for the Phobos project designed to send two probes to Phobos, one of the two moons of Mars. Many Soviet papers have been presented at international meetings over the past several years on the details of this project, and although the probes were launched in the summer of 1988, which is beyond the purview of this report, it would be a glaring oversight to leave them out.

As recounted in the historical summary, the Soviets have been plagued by failures at Mars and at the end of 1988 when this report was being completed, it seems that the bad luck is still haunting them. One of the two probes, Phobos 1, was declared dead in October, and Phobos 2 is experiencing problems. Unless otherwise indicated, the following discussion refers only to Phobos 2, which is scheduled to reach Mars on January 29, 1989. At that

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[38] Bohlen, Celestine. Soviet VEGA 2 Passes Closer to Comet. Washington Post, Mar. 10, 1986. p. A 23.

[39] Lenorovitz, Jeffrey M. Both Soviet VEGA Spacecraft Relay New Data From Halley. Aviation Week and Space Technology, Mar. 17, 1986. p. 18.

[40] VEGA's 1 and 2 Visit Halley. Science, Mar. 21, 1986. p. 1366.

[41] VEGA's 1 and 2 Visit Halley. Science, Mar. 21, 1986. p. 1366.

[42] Vestnik Akademii Nauk SSSR, Aug. 1986, p. 17–20.

[43] Balebanov, V. The Vega Project: the Concluding Stage. Sovremennyye Dostizheniya Kosmonavtiki (Novoye v Zhizni, Nauke, Tekhnike: Seroya Kosmonavtika). Astronomiya, Dec. 1986. p. 17–34. English Translation: JPRS–USP–87–003, Apr. 22, 1987.

[44] Izvestiya, Jan. 16, 1987, p. 2.

time, the world will know whether or not the Soviet luck has finally changed. [Note: In March, 1989, contact with Phobos 2 was lost.]

The Phobos program involves even more international participation than VEGA, and with improved relations between the superpowers, U.S. involvement is being openly discussed by both sides. The United States again is assisting in tracking the probes, specifically the Phobos landers. Other cooperative experiments, related to studies of the Sun, were to have been conducted with equipment on Phobos 1 and the U.S. Solar Maximum Mission satellite, but the loss of Phobos 1 cancelled those plans. Austria, Bulgaria, Ireland, Hungary, East Germany, Poland, West Germany, Finland, France, Czechoslovakia, Switzerland, Sweden, and the European Space Agency are all participating in the Phobos program.

The Phobos Spacecraft

The Phobos spacecraft were designed by the Babakin Institute, with IKI serving as program manager. The three-axis stabilized spacecraft each weigh 6,220 kg [45] and cost 300 million rubles.[46] A variety of instruments are carried for studies enroute to Mars, of Mars itself, and of Phobos. The instrument complement was almost identical on Phobos 1 and Phobos 2, but some experiments were specific to the probe. Unfortunately, the Terek x-ray telescope for studying solar fluctuations was only on Phobos 1, as was the SUFR experiment to study ultraviolet solar radiation. One other instrument, the Soviet IPNM experiment to study neutron radiation from the surface of Phobos, was also only on Phobos 1.[47] Figure 5 shows the Phobos spacecraft design.

Two cosmic ray detectors are aboard. The LET, developed by Hungary, France, West Germany and the Soviet Union, will study cosmic rays in the 0.9–75 Megaelectronvolt (MeV) range, while SLED, built by Hungary, West Germany and the Soviet Union, will study low energy particles, including 20–140 kiloelectronvolt (keV) electrons, 20 keV–3.4 MeV protons, and 0.1–3.4 MeV helium nuclei.[48]

High resolution (6 centimeter) television pictures will be taken of Mars and Phobos using a three-channel television system called Fregat. The system weighs 50 kg[49] and was developed with the cooperation of Bulgaria and East Germany.[50] (Reports at the end of 1988 indicated that this was one of the Phobos 2 instruments that was experiencing problems.)[51]

There is a combination radiometer with angular resolution 30', photometer with angular resolution 16', and infrared spectrometer with angular resolution of 12'. The spectral subbands are divided into 10 parts for the photometer, 128 for the spectrometer, and 6

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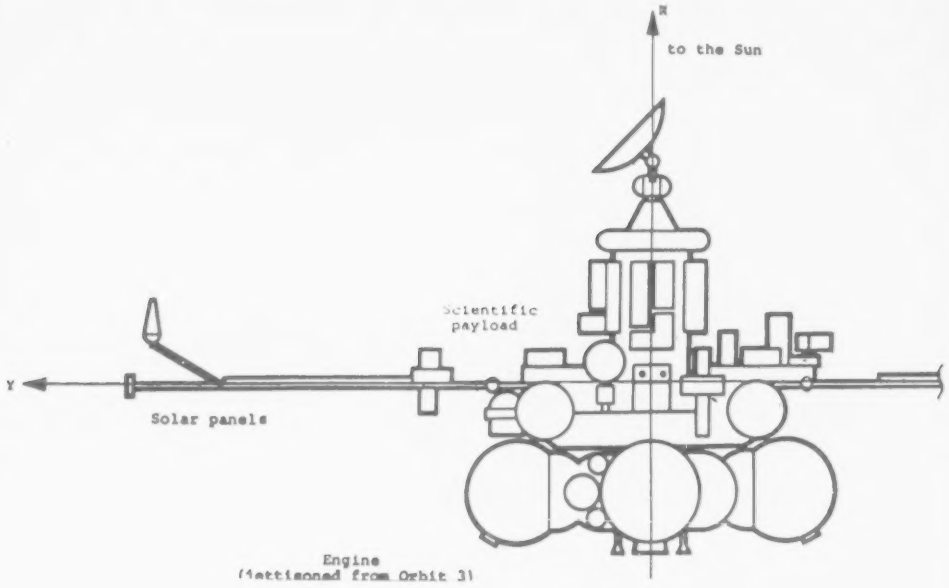
[45] Phobos 1 Loss to Change Mars Mission. Aviation Week and Space Technology, Oct. 3, 1988, p. 29.
[46] Sotsialisticheskaya Industriya, July 9, 1988, p. 3.
[47] Loss of Contact with Phobos-1 Spacecraft. Science and Technology Perspectives, Oct. 7, 1988, p. 10.
[48] East Europe: Contributions to Phobos Mission. Foreign Broadcast Information Service. Science and Technology Perspectives, Oct. 3, 1988. p. 4.
[49] Kidger, p. 275.
[50] East Europe: Contributions to Phobos Mission, op. cit., p. 3.
[51] Phobos 2 Experiences Payload Problems. Aviation Week and Space Technology, Jan. 2, 1989. p. 38.

Figure 5.—The Phobos Spacecraft



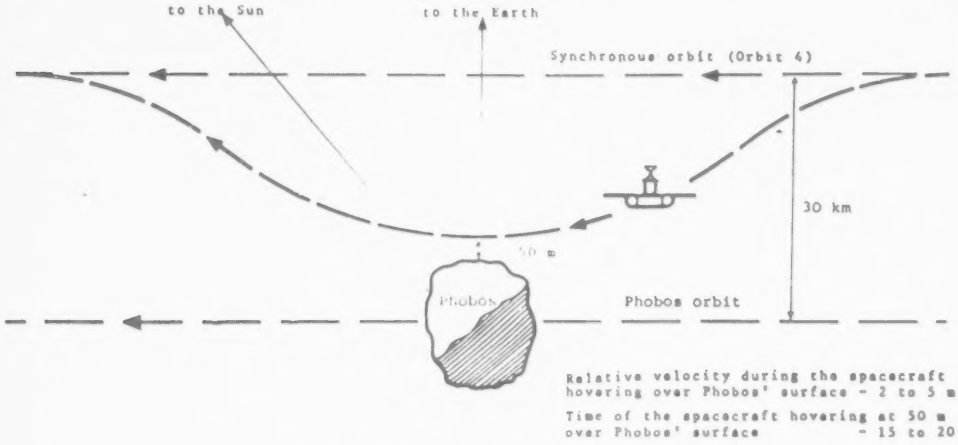
for the radiometer. The radiometric and photometric instruments will provide data which will be used to make surface temperature maps of Mars and Phobos, and for Mars will include a search for permafrost regions. Data from a gamma spectrometer will analyze the basic rock-forming elements and natural radioactive elements. The atmosphere and ionosphere of Mars will be investigated, again with French participation, looking for information on the vertical distribution of the concentration of ozone, water vapor, molecular oxygen and dust; of vertical temperature and pressure profiles; of seasonal, diurnal and local variations in atmospheric parameters; and of the ratio of deuterium to hydrogen to examine the question of why liquid water disappeared from the planet's surface. Some of the atmospheric studies will be made using pulsed radiosondes. An East German magnetometer called the FGMM–1 (Flux Gate Magnetometer Mars-1) and weighing 4 kg will study Mars' and Phobos' magnetic fields, if any.[52]

There are specialized instruments for studying Phobos which are varied and scientifically exciting, as is the flight profile the Soviets will use to study the moon. When it reaches Mars in late January 1989, Phobos 2 will enter a very elliptical orbit around Mars and then gradually maneuver into a circular "observation" orbit at an altitude of 6,330 km. The spacecraft will spend approximately 30 days in this orbit observing Mars and Phobos, and then move into an orbit that is synchronous with Phobos (altitude approximately

[52] Izvestiya, Oct. 7, 1988, p. 5.

6,000 km) and remain there for up to 90 days.[53] During the latter period, the probe will move into position and hover over Phobos at an altitude of only 50 meters for 15–20 minutes. Its speed will be 2–5 meters per second. The probe's trajectory for this stage of the program is shown in figure 6.

Figure 6.—Planned Trajectory of Phobos Spacecraft Near Phobos


to the Sun
to the Earth
Synchronous orbit (Orbit 4)
30 km
50 m
PHOBOS
Phobos orbit
Relative velocity during the spacecraft hovering over Phobos' surface - 2 to 5 m
Time of the spacecraft hovering at 50 m over Phobos' surface - 15 to 20

The Phobos-specific experiments include a 70 kg laser[54] called Lima-D with an energy of 1 Joule that will be aimed at a small section of the surface of Phobos (1 square millimeter) for 10–8 second.[55] The energy density at that spot will be more than 10 milliwatts. The laser has a beam wavelength of 1.06 microns and a pulse rate of 0.1–0.2 Hertz.[56] The laser will vaporize the surface material and a mass spectrometer on the spacecraft then will determine the chemical composition of the particles thrown in its direction. The reflectron was designed by Bulgaria; East Germany made the optical components; Czechoslovakia and the Soviet Union built the range-finding system and a special lens for focussing the ray; and West Germany provided the computers for onboard processing of information.[57] Between 150 and 200 "shots" will be taken at Phobos.

Phobos 2 also has an ion gun, called Dion, that will accelerate krypton ions to two-three keV to strike secondary ions on the surface which will be registered by the spacecraft's mass spectrometer.

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[53] Kovtenenko, et al. Phobos—A Multipurpose Mission for Investigation of Phobos, Mars, The Sun and Outer Space. Astronomicheckiy Vestnik, Oct.-Dec. 1987. p. 278–285. English Translation in JPRS-USP-88-004-L, Apr. 11, 1988.

[54] Kidger, Neville. Project Phobos: A Bold Soviet Mission. Spaceflight, July 1988. p. 275.

[55] Balebanov B. et al. Project Phobos: Mars's Mysterious Moons. Science in the USSR, July-Aug. 1986. p. 3–11; Kidger, Neville. Project Phobos: A Bold Soviet Mission. Spaceflight, July 1988. p. 275. Two Western sources says the energy of the laser beam is 0.5 Joule (Spaceflight, July 1988, p. 275; and Aviation Week and Space Technology, June 16, 1986, p. 92.)

[56] Lenorovitz, Jeffrey M. Soviets Test Spectrometric Laser System. Aviation Week and Space Technology, June 16, 1986. p. 92.

[57] Managadze, G. Leninskoye Znamya, Oct. 14, 1986. p. 4. English translation in JPRS-USP-87-001, Feb. 19, 1987.

Dion weighs 18 kg and was built by Austria, France and the Soviet Union.[58]

There is a radar called GRUNT for investigating Phobos' internal structure. The 35 kg experiment can probe the surface of Phobos to a depth of 2 meters,[59] but one Western report said that this was only on Phobos 1.[60]

Phobos 2 carries two Phobos landing probes. One is a "hopper" that can move around the surface of the tiny moon, while the other, called the LAS, will be fixed to the surface to make longer term studies. The hopper will move along the surface of the moon by using a pushing device to "hop" 20 meters at a time. One instrument on the lander will study the strength, adhesion, compressibility and viscosity of the soil.

The LAS will be held in place by a probe sunk by a pyrotechnic charge. Then solar panels will be unfurled to provide electricity, and the instrument platform will lift itself 80 centimeters above the surface.[61] The LAS has six experiments: a radio beacon to be used for determining the parameters of Phobos' motion around Mars and the motion of Mars in the solar system; a seismometer to record the noise caused by the gravitational pull of Mars, the thermal expansion of the rock during the diurnal cycle, and the impact of meteorites; an x-ray fluorescence spectrometer for determining chemical composition of the surface; a system of Razrez sensors housed in a penetrometer for studying physicomechanical properties; and a panoramic television system.[62] The LAS was built by Hungary, France, West Germany and the Soviet Union and carries 30 kg of scientific equipment.

The Journey to Mars and the Loss of Phobos 1

Phobos 1 was launched with a Proton launch vehicle from the Tyuratam launch site on July 7, 1988. The Soviets invited a large contingent of Western observers to see the launch, and some stayed for the launch of Phobos 2 on July 12. Reflecting the greater commercial nature of the Soviet space program, the Proton booster for Phobos 2, which was still in the assembly area at the time of the Phobos 1 launch, was covered with advertisements from two European firms, neither of them space related (Voest Alpine, an Austrian engineering firm, and Danieli, an Italian firm that provides steel factories to the Soviet Union).[63]

On August 31, 1988, a ground controller sent an incorrect command to Phobos 1, inadvertently ordering it to turn off its attitude control system.[64] The Soviets became aware of the problem on September 1 when they tried to reestablish routine communications with the spacecraft. Reviewing the most recent commands that had

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[58] East Europe: Contributions to Phobos Mission, op. cit., p. 3.

[59] Kidger, p. 275.

[60] Phobos 1 Loss to Change Mars Mission. Aviation Week and Space Technology, Oct. 3, 1988. p. 29.

[61] Balebanov, et. al. Science in the USSR.

[62] East Europe: Contributions to Phobos Mission, op. cit., p. 4.

[63] Lenorovitz, Jeffrey M. Launch of Two Phobos Spacecraft Begins Ambitious Mission to Mars. Aviation Week and Space Technology, July 18, 1988. p. 16–18.

[64] Moscow in English to Great Britain and Ireland, 2000 GMT, Oct. 12, 1988. This announcement quotes Dr. Roald Sagdeyev, then head of IKI, so is used as the source for this information. Most other Western sources, however, say that the incorrect command was sent on Aug. 29, and the Soviets became aware of the problem on Sept. 2 when they tried to reestablish contact.

been sent, they discovered the controller's mistake. Since communications were lost, scientists can only speculate as to exactly what happened after the mistaken command was received by Phobos 1, but the consensus is that having lost its correct orientation, it began tumbling and the solar panels were no longer pointed towards the Sun. Thus they could not be recharged and, after a short period of time, died.

The Soviets formally announced the difficulties with Phobos 1 on September 9.[65] In mid-October, they stated that they had given up all hope of reestablishing contact with the probe after determining there was no hope of any energy being left in the batteries.[66] Before communications were lost, 140 x-ray images of the Sun had been received.[67]

Phobos 2 continued on its intended course and in November the Soviets reported on systems tests, and the tracking of the spacecraft by Soviet and American tracking stations. In December, however, rumors began to circulate in the West that problems had now developed with Phobos 2. On December 29, TASS issued a statement that most of the malfunctions aboard the spacecraft had been repaired, and "the rest won't prevent the research program from being carried out in full."[68] No specifics were given as to what systems or experiments had malfunctioned, but a report in a U.S. trade magazine quoted Dr. Galeev, now head of IKI, as saying that some of the channels on the television system have failed and only the optical range remains, and difficulties are being experienced with data collection from certain experiments and they "need a little push" to give data.[69]

Phobos 2 is scheduled to arrive at Mars on January 29, 1989, and to study Phobos in early April.

Future Proposals and Plans

For the first two and a half decades of spaceflight, the Soviets rarely discussed their space science plans in the West. Launches that failed were given generic Cosmos designations and no announcement was made about their intended purpose, leaving Western analysts the task of discerning their missions from available clues. As discussed under the section on the FASAC report (above), little information was available even from the successful Soviet probes.

The new Soviet policy of *glasnost*, coupled with the increasing trend towards international participation in space science missions, has changed that situation dramatically. The international involvement makes it virtually impossible for the Soviets to hide failures, and *glasnost* permits Soviet scientists the freedom to discuss future proposals and plans.

There is a significant difference between a proposal and a plan, however, and perhaps because Western scientists were so unaccus-

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[65] TASS, 0922 GMT, Sept. 9, 1988.
[66] Moscow in English to Great Britain and Ireland, 2000 GMT, Oct. 12, 1988.
[67] Pravda, Nov. 4, 1988, p. 1.
[68] Quoted in: Soviets Say Problems with Phobos II Probe Have Been Rectified. Aerospace Daily, Dec. 30, 1988. p. 475.
[69] Phobos 2 Experiences Payload Problems. Aviation Week and Space Technology, Jan. 2, 1989. p. 38.

tomed to the Soviets discussing their future proposals, there was the assumption on the part of many that the Soviets were talking about concrete mission plans that already had government approval. This is not the case, however, as proven not only by direct Soviet statements, but also by the number of missions first brought up in the 1986–1987 time period that have already changed dramatically in terms of launch date and mission objective as detailed below.

Considerable concern was expressed by Western space scientists and the media that the Soviets were "taking the lead" in space science, especially solar system exploration, by virtue of all the plans they had announced. A comparison of U.S. solar system exploration plans for the rest of the century with Soviet plans is contained in the Executive Summary and will not be repeated here except to emphasize that the United States has sent probes to solar system destinations from Mercury to Uranus, and has three approved programs for launch in 1989 and 1990. Even if the Soviets successfully completed every project they have proposed through the year 2000, they could not hope to catch up with the data already gained by U.S. probes, and that will likely result from the approved missions.

The tendency to turn every space activity into a race between the superpowers is discouraging, and, in fact, surprising in today's reality of extensive international cooperation in both the U.S. and Soviet programs. The following list of what the Soviets have stated are their proposals and plans for the future simply lays out what the road ahead may be if the Soviet government ultimately approves these projects. To provide a comparison, a list of missions proposed in NASA's Solar System Exploration Committee 1983 and 1986 reports and the 1988 U.S. National Academy of Sciences 7 volume series on space science in the 21st century would have to be set forth.[70] That is not the objective of this report, however, so only the Soviet proposals are summarized.

Most of the Soviet proposals were described at the October 1987 Moscow Space Future Forum held in connection with the 30th anniversary of the launch of Sputnik. The Soviets prepared three papers for that symposium: the first on "near space" which describes earth orbiting solar-terrestrial physics proposals, the second on solar system exploration (planets and small bodies), and the third on "deep space" which concerns earth orbiting missions for astronomical studies. Except as otherwise noted, the information in this section is from those three unpublished papers.[71]

It should be noted that several science missions (Aktivniy, Granat and Gamma-1) were planned for 1988, but none were launched. As recently as April 1988, Dr. Balabanov, a deputy director of IKI, referred to the fact that Granat and Gamma-1 would be launched by the end of the year.[72] What problems developed in

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[70] U.S. National Aeronautics and Space Administration. NASA Advisory Council. Solar System Exploration Committee. Planetary Exploration Through the Year 2000: A Core Program. Planetary Exploration Through the Year 2000: An Augmented Program. Washington, NASA, 1983 and 1986.

U.S. National Academy of Sciences. Space Science in the 21st Century: Imperatives for the Years 1995-2015. Washington, National Academy of Sciences, 1988. 7 volumes

[71] Dr. Roald Sagdeyev published on article in the May 1988 issue of Physics Today which summarizes many of these programs and proposals.

[72] Moscow in English to North America, 2200 GMT, Mar. 31, 1988.

this launch schedule are unknown, although the fact that Granat's launch would be delayed until 1989 was revealed just one month later by Dr. Sagdeyev.[73]

EARTH ORBITAL MISSIONS FOR SOLAR/TERRESTRIAL PHYSICS

Interbol [74]

The Interbol program is a cooperative effort among the Soviet Union, Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Poland, Romania, Austria, Canada, Finland, France, Sweden and the European Space Agency. Launch is planned for the 1990–1991 time frame. Two Prognoz satellites will be launched, each carrying a Czech sub-satellite. Data will be gathered on processes in the auroral zone and in part of the magnetosphere's tail closest to Earth, while simultaneous observations will be made with the Relikt-2 satellite (see next section) of the plasma and magnetic patters of the far regions on the tail. This will aid in understanding the nature of the magnetosphere as a single system. The auroral probe will be placed into a 20,000 x 500 km orbit at 65 degrees inclination.[75] The tail probe will use a 250,000 x 500 km orbit also at 65 degrees.

Apex (Active Plasma Experiments)

Participants in this project, whose launch date is expected to be 1989, are Hungary, East Germany, Bulgaria, Poland, Romania, the Soviet Union and Czechoslovakia. This project would involve injecting electron beams and plasma bunches into the magnetosphere with the following objectives: modeling and initiation of polar lights and radio emissions in the auroral sphere; study of the dynamics of modulated beams and plasma bunches in the near-Earth plasma; study of the nature of the electrodynamic connection between electromagnetic waves in the magnetosphere and ionosphere; determination of the radio emission properties of charged particle beams and plasma bunches; and search for non-linear wave structures in disturbed conditions. Along with the spaceborne observations will be ground-based, balloon and rocket observations.

Active-IK (Aktivniy)

At the 1987 Moscow Space Future Forum, Active-IK (also called Aktivniy) was listed as having a launch date of late 1988, but it was not launched by the end of the year. Participants in the project are Hungary, East Germany, Bulgaria, Poland, the Soviet Union, and Czechoslovakia.

Some of the objectives of the project are similar to those of APEX, except that instead of electron beams, very low frequency waves will be used to influence the magnetosphere. The principal objectives are to study the spread of the VLF waves in the magnetosphere and study how they interact with energetic charged particles in the radio belts. The satellite will carry a 5 kilowatt transmitter operating at 10 kilohertz with a 20 meter diameter antenna.

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[73] Sagdeyev, Roald Z. Soviet Space Science. Physics Today, May 1988. p. 31.
[74] Alternatively spelled Interball.
[75] Lanzerotti, et al. Soviet Space Science Research. McLean, VA., Science Applications International Corp., Jan. 31, 1986. FASAC-TAR-3060. p. II-11.

A Czech subsatellite will be used for complementary measurements. A plasma generator and neutral gas (xenon) injector will also be used.

Coronas

For this project, the Soviet Union is working cooperatively with East Germany, Poland and Czechoslovakia, with a proposed launch date in the 1990–1992 time frame. The project's objective is to study solar eruptions, and will carry an x-ray telescope and a heliometer. According to the Soviets, this satellite will be the first to carry a helioseismometer which can register five-minute oscillations.

EARTH ORBITAL MISSIONS FOR TRONOMY

As noted earlier, the FASAC analysis of Soviet space science concluded that the Soviets had not made any significant contributions in space astronomy. In 1988, Soviet astronomer Grigor Gurzadyan publicly concurred, saying that space astrophysics had been "unjustifiably neglected by both scientists and information media as compared with astronomy using equipment on the ground."[76] Nevertheless, several astronomical missions have been listed as being in the planning or proposal stage, but the launch dates do seem to continually slip.

Granat

At the 1987 forum, this mission was listed with a 1988 launch date, although by May 1988 Dr. Sagdeyev wrote about it as having a 1989 launch date.[77] Participants in the project are Denmark, France, Bulgaria and the Soviet Union. The observatory will carry 2,300 kg of scientific instruments and be placed into a highly elliptical orbit (apogee 200,000 km) similar to the Astron satellite. The Soviet-made ART-P and ART-S instruments will provide images, energy spectra and timing and in the 3–100 keV band, while the French Sigma telescope will image the sky in hard x-rays and soft gamma rays.[78] Granat will also carry several instruments to study gamma ray bursts in the 2 keV to 100 MeV range. Some of the special objects of study for Granat will be x-ray pulsars, hot plasma in galaxy clusters, and regions surrounding black holes.[79]

Spectrum-Roentgen-Gamma

This is a proposed project for launch in late 1992 or early 1993 and involves researchers from Australia, Bulgaria, Britain, Hungary, East Germany, Denmark, Italy, the United States, Poland, Finland, France, West Germany, Czechoslovakia and the European Space Agency in addition to the Soviet Union.[80] Objects to be studied would include binary stars, pulsar magnetospheres, inner regions of galactic nuclei, supernova remnants, and the origin of gamma ray bursts. The mission's objective is to better understand

[76] Literaturnaya Gazeta, May 4, 1988, p. 11.
[77] Sagdeyev, Roald Z. Soviet Space Science, op. cit.
[78] Sagdeyev, Roald Z. Soviet Space Science. Physics Today, May 1988. p. 31.
[79] Trud, Oct. 3, 1986, p. 3.
[80] TASS, 2104 GMT, Sept. 8, 1988.

the structure and evolution of the universe and obtain new data about distant galaxies and other astronomical objects.

Two satellites[81] would be used for this program, one in an orbit with a high apogee (200,000 km) and one with a low apogee (400 km). The first satellite would have 2,500 kg of scientific equipment consisting of instruments creating images with the help of both telescopes with mirrors of oblique and normal incidence, and instruments with encoded aperture. It will be able to study energy ranges from 0.02 to 100 keV. The spacecraft probably will have two large x-ray telescopes with grazing incidence optics and 8-meter focal lengths, and are being developed cooperatively with Denmark.[82] The low apogee satellite will carry equipment to enable temporary monitoring and spectroscopy with moderate energy resolution in the soft and medium roentgen bands and the creation of images and spectrometry with high energy resolution in the hard roentgen and soft gamma bands (15 keV to 10 MeV).

Gamma-1

The Soviets announced on April 29, 1985, that "just now preparations are underwaym to launch" the Gamma-1 observatory.[83] Six months later, a Western press report said that the launch (originally scheduled for 1984) had been delayed to late 1986 or early 1987 because of "planning problems."[84] At the 1987 Moscow Space Future Forum, the Soviets said it would be launched in early 1988. It had not been launched by year's end. The satellite is being built by the Soviet Union, Poland and France.

Gamma-1's objective is to study high-energy gamma rays using a spark broad-gap camera that will improve the spatial accuracy of pinpointing the sources of gamma ray bursts. Instruments reportedly include a 50 MeV–5 GeV Spark Chamber with coded mask (built with France), a 0.2–2 MeV Scintillation Detector (150 square centimeters), and 2–20 keV Proportional Counters (600 square centimeters total) with coded mask for x-ray bursters, transients and pulsars.[85] According to Western reports, the observatory will be housed in a Progress spacecraft[86] an· will weigh 1,500 kg.[87]

Aelita

No launch date was announced for this project which was proposed by IKI at the Moscow Space Future Forum. The objective of this proposal is to make cosmological and astrophysical studies in the submillimeter range to study the origin and evolution of the universe. The observatory would be cryogenically cooled with a 1

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[81] The information about the two satellites is from the 1987 Moscow Space Future Forum paper. In Sept. 1988, however, a Soviet scientist identified as the research director for the project, Rashid Syunyayev, was interviewed about the project and mentioned only one spacecraft (TASS, 0843 GMT, Sept. 6, 1988; TASS, 2104 GMT, Sept. 8, 1988; and Moscow in Serbo-Croatian to Yugoslavia, 2000 GMT, Sept. 29, 1988). Sagdeyev's 1988 Physics Today article (op. cit.) also mentions only one satellite.

[82] Sagdeyev, Physics Today, op. cit., p. 31.

[83] Moscow World Service, 0831 GMT, Apr. 29, 1985.

[84] Soviet Observatory. Aviation Week and Space Technology, Oct. 7, 1985. p. 50.

[85] Technical details on Gamma-1 were published in Astronomicheskiy Zhurnal, Sept.-Oct. 1986, p. 856–866. English translation in JPRS-USP-87-003L, Apr. 9, 1987. The FASAC report (supra) also gives some information on the project on p. IV-7.

[86] Progress is the cargo resupply craft used in the Soviet space station program. See Part 1 of this report for further information.

[87] Soviet Observatory. Aviation Week and Space Technology, Oct. 7, 1985. p. 50.

meter diameter telescope with a spectra range of 0.15 to 2 millimeters, a 3 to 15 minute of arc field of view, with cooling accomplished with a 400 kg supply of cryogenic agents (superfluid helium4 and liquid neon) providing a stable temperature of 27 K for the telescope optics.[88] One Western report states that the launch date is in the 1993–1994 period.[89]

Relikt-2

Proposed for launch in the 1992–1993 time frame, Relikt-2 would follow up on studies made by Prognoz 9, and similarly would study the origin and evolution of the universe based on studies of background radiation.

Radioastron

Radioastron is usually described as a single satellite with a 10 meter diameter antenna for radio astronomy studies to be launched in the early 1990s. At the Moscow Space Future Forum, however, it was described as a three-stage program using satellites to be launched in the 1991–1996, 1996–2000, and 2001–2005 time frames. The satellites would be part of a very long baseline interferometry (VLBI) network to study the universe at radio wavelengths. Radioastron-cm (launched in the 1991–1996 time frame) and Radioastron-mm (1996–2000) would be placed into orbits with an apogee of 700,000 km (like Prognoz 9), and would work with ground-based radio telescopes and (presumably if they are in orbit and operating simultaneously) with each other. The third stage of the program, called Radioastron K–K, would involve three different spacecraft, each with 30 meter diameter telescopes, which would also work with each other and with ground-based telescopes. One would be located in geostationary orbit, another in an elliptical orbit with a period of 27 days; and a third (at a Sun-Earth libration point) with a period of 365 days. Jointly, they would produce three-dimensional pictures of objects in the galaxy.

Among the objects to the studied in this proposed program are: cores of active galaxies and quasars; galactic relativistic objects; neutron stars; black holes; flare-up stars and stars with matter emissions; space masers in the fields of star formation and planetary systems; the center of the Milky Way; and the interstellar medium. Objectives of the research include: fundamental cosmological constants and a model of the expanding universe; nature of the central energy source in the cores of galaxies and quasars; cosmological evolution of compact size sources; nature of emissions from objects with maximum brightness temperature; links between radio emissions from compact sources with emissions in other parts of the spectrum; physical processes involved in the formation of stars and planetary systems; structure of the atmosphere of neutron stars, locality of the fields of radio emissions of pulsars and discovery of near-pulsar envelopes; physics of relativistic galactic objects—neutron stars and black holes in double systems; the structure of the interstellar plasma; and irregularities of the Earth's ro-

[88] Foreign Broadcast Information Service. Science and Technology Perspectives, Apr. 8, 1987. p. 6.
[89] Ibid.

tation and changes in the position of its poles, study of geotectonics and internal structure of the Earth.

The first Radioastron satellite will operate at 327 (or 408), 165, 4900 and 22,235 Megahertz (MHz).[90] Discussions have been underway for several years about the possibility of Western scientists cooperating with the Soviets in space-based radio astronomy studies. U.S. and European scientists have been proposing a project called QUASAT which would complement the Soviet work, but has not been approved yet.

PLANETARY EXPLORATION

One of the three papers at the Moscow Space Future Forum in October 1987 was on planetary exploration, and the lengthy list of proposed missions is summarized below.

The Soviet proposals had been revealed over a period of almost three years. At the 16th Annual Lunar and Planetary Science Conference in Houston, TX., in March 1985, the Soviets gave an unusually open presentation about future proposals, including several probes to Mars, the Vesta asteroid proposal, and lunar probes.[91] Two years later, in May 1987, at a meeting sponsored by the American Institute of Aeronautics and Astronautics in Pasadena, many of these proposed missions were presented again, some with more specific details.

An extremely important aspect of these papers, however, was the caveat the Soviet authors put on the contents of the lists. At the May 1987 AIAA meeting in Pasadena, the Soviets stressed that no phase of the program they were presenting had yet been approved by the Soviet government.[92] Despite this cautionary statement, one U.S. scientist attending the meeting was quoted as saying that he was "envious" of the Soviet program and that it represented a "remarkable commitment," while another said the Soviets were "in the process of passing us in solar system exploration."[93] Such comments demonstrate the tendency of some U.S. space scientists to overdramatize the significance of the Soviet proposals. In the paper presented at the October 1987 Space Future Forum, participants were reminded that only the Phobos project was actually underway, and that "there are good reasons to believe" the 1994 Mars mission would be included "in the official Soviet program of studies of the solar system." As for the others projects, the Soviets stated: "The destiny of the VESTA project depends greatly on the CNES and ESA decision to create an asteroid module which should be taken in 1988. *The capability to implement the other projects is not so evident.*" (italic added) Thus, when reviewing these proposals, it must be repeatedly stressed that they are just that, proposals, not approved programs.

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[90] Technical details on Radioastron were published in Andreyanov, et al. Astronomicheskiy Zhurnal, Sept.-Oct. 1986. p. 850-855. English translation in JPRS-USP-87-003L, Apr. 9, 1987. p. 8-15.

[91] Covault, Craig. Soviets in Houston Reveal New Lunar, Mars, Asteroid Flights. Aviation Week and Space Technology, Apr. 1, 1985. p. 18-20.

[92] Smith, Bruce A. Soviet Scientists Present Details of Mars Exploration Program. Aviation Week and Space Technology, May 25, 1987. p. 22.

[93] Sawyer, Kathy. Soviets Unveil Plan for Mars Missions. Washington Post, May 26, 1987. p. A16.

Mars

Mars 1994

As described at the Moscow Space Future Forum, the next mission to Mars after Phobos would be named Columb (elsewhere the name was listed as Columbus) and was scheduled for a 1992 or 1994 launch. The mission would involve the use of French balloons similar to those used on the VEGA probes, an orbiter, and a surface rover with a sensor sinking system and soil sampler.

Currently, this mission is referred to simply as "the 1994 Mars mission," and the 1987 paper listed the following as suggested instruments for the orbiter, balloon, penetrator, and rover. The *orbiter* would be in polar orbit with a 12 hour period carrying a 1 meter resolution TV system, a gamma spectrometer, a scanning infrared radiometer, a Fourier spectrometer or multiband radiometer for infrared sounding of the atmosphere, a video spectrometer, two optical spectrometers (one for atmospheric sounding using the solar and stellar eclipse method, the other for measuring the upper atmosphere radiation spectrum), a radiometer for mapping water, oxygen and carbon monoxide, a neutral mass spectrometer, an ion mass spectrometer, a magnetometer, a plasma package, and instruments for solar oscillation studies and cosmos gamma burst studies.

The *balloon* would have an active lifetime of 15–50 days covering 100–400 km per day. Suggested experiments included: a panoramic TV camera with one millimeter resolution, a 0.1 meter resolution TV camera for surveying from an altitude of 200 meters, a meteorological package, a photometer, and instruments for electromagnetic sounding of the subsurface layer; studies of alpha backscattering and x-ray or gamma ray spectrometer; and differential temperature analysis and analysis of volatiles.

There would be "several" *penetrators* with a lifetime of 1–4 years and including a seismometer, instruments for soil composition analysis and thermal flux measurements, and a meteorological package.

The *rover* would have a range of about 300 km and carry a soil sampler to a depth of 3–10 meters. It would also carry a TV system, a gamma spectrometer, a device for analyzing soil volatiles, a microscope for analyzing soil microstructure, a meteorological package and one for electromagnetic soil sounding, a seismic sounding package, and a package for investigating soil samples for biological activity. The Soviets have said that they are testing a Martian rover prototype on the Kamchatka Peninsula.[94]

At the end of 1988, the Soviets reportedly were considering changing the mission once again, having the orbiter, balloon, and penetrators, but delaying the rover until 1996.[95] Another Western report quoted Soviet scientist Genrish Avanesov as saying that the entire 1994 mission might be delayed until 1996 because although the Soviets were technically capable of doing the mission, "we're not sure it's worth doing" and admitting that "Money is a problem

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[94] Smith, Bruce A. Soviet Scientists Present Details of Mars Exploration Program. Aviation Week and Space Technology, May 25, 1987. p. 22.

[95] Soviets Revise Mars Program; Prepare Mission to Moon. Aviation Week and Space Technology. Jan. 2, 1989. p. 39.

for today for us, too." He emphasized that no official decision had been made on the timing of the mission.[96]

Dr. Sagdeyev, who is the mission science director following his resignation from directing IKI, reportedly was stunned by the statements by his colleagues about the possible mission delay, saying that "We were told by the president of the Soviet Academy of Sciences that Mars-94 is an approved mission. He also told [this to] the French, who have now started much work on the balloon portion of the flight. . . . I think that it is really a worrisome situation."[97] The potential delay had been voiced by Soviets at a joint U.S./Soviet working group meeting in Washington. The United States has agreed to place a relay transmitter on its Mars Observer spacecraft (to be launched in 1992) to assist in communicating with the balloons. The two countries are discussing other possible cooperation for the two missions as well.

Future Mars Exploration

The other Mars missions listed in the Space Future Forum paper were a 1996 mission to return a sample of Martian soil to Earth, followed by another sample return mission in 1998, and a long term, long range (1000 km) rover for 2002. At the May 1987 AIAA meeting, the sequence mentioned had been somewhat different. After the 1992/1994 orbiter/lander/balloon mission, the Soviets listed a 1994/1996 mission carrying a larger rover, although they stressed that it was not a definite part of the program at that time. The sample return missions were to follow the large rover.[98] At the May 1987 meeting, both the 1992/1994 and 1994/1996 missions were reported to include sample return devices, although this has not been mentioned since by the Soviets.

In his May 1988 Physics Today article, Dr. Sagdeyev commented that "The likelihood of implementing the mission to Mars in 1994 and the sample return mission before 2000 depends mainly on the development of space technology." He noted the need for a launch vehicle with a high energy upper stage (although he did not mention using the new heavy-lift Energiya launch vehicle, which reportedly has been the subject of some controversy in the Soviet space science community), the development of aerobraking technologies, and "many other problems as well—in particular, the problem of the Martian soil quarantine on Earth." He concluded that "From our viewpoint, however, it looks like these problems can be solved in the years ahead."[99]

At the end of 1988, a Soviet scientist, Vladimir Tarnopolsky, suggested that the United States and Soviet Union each build rovers for coordinated missions (see also the section on U.S./Soviet cooperation below).[100] He suggested that a Soviet "pioneer" rover could travel to a new site every day to gather a great deal of information on different locations, and a U.S. rover could then land on one of

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[96] Space Commerce Bulletin, Dec. 16, 1988, p. 8.

[97] Covault, Craig. Perestroika in Space, Science Controversial to Soviet Officials. Aviation Week and Space Technology, Dec. 12, 1988. p. 34-35.

[98] Smith, Bruce A. Soviet Scientists Present Details of Mars Exploration Program. Aviation Week and Space Technology, May 24, 1987. p. 2.

[99] Sagdeyev, Roald Z., op. cit , p. 37.

[100] Soviets Propose Joint Martian Infrastructure. Defense Daily, Dec. 2, 1988. p. 166-167.

the safe sites discovered by the Soviet probe to perform more detailed studies. The Soviet rover described by Tarnopolsky would have a mass of 250 kg and travel at 0.2 meters per second on six conical wheels that would be individually powered by a thermal electric generator. It would also have a manipulator arm. To obtain a clear view in front, the Soviets are proposing a kite-mounted camera raising it tens or hundreds of meters into the air, called Skylift. A balloon or a system to pop microcameras into the air are being studied as alternatives. Tarnopolsky conceded that the Skylift idea was "close to science fiction" in terms of its novelty.[101]

Another proposal that sounds like science fiction was described in February 1987 by Dr. Nikolay Umnov.[102] Called a "hexapod", it would be a rover that could "walk" on the surface of Mars to transport cosmonauts around the planet. The report described a prototype being tested at the Machine Engineering Institute of the Soviet Academy of Sciences that was a meter and a half long with six metal legs that could step over obstacles like rocks. The prototype could travel at a speed of 10 centimeters a second, but the operational vehicle would travel at 80–100 kilometers per hour, using pneumatic motors. Studies of insects, including the cockroach, "the most stable of insects," led to the choice of six legs.

The Moon

In 1985, the Soviets announced a proposal to launch a lunar polar orbiter in 1989–1990.[103] The Moscow Space Future Forum included three lunar missions in its long list of proposals: a 1993 lunar polar orbiter; a 1996 sample return from the far side of the Moon; and a year 2000 deployment of a large automatic station with rovers. Interestingly, even though missions to the outer planets seem much more speculative for the Soviets, they were listed with a set of prospective instruments and objectives to be met, but there were no comparable lists for the lunar probes. Among the instruments mentioned two years earlier for the orbiter were: TV camera, gamma ray spectrometer, X-ray spectrometer, neutron detectors, spectrophotometer, infrared spectrometer, radar altimeter, charged particle spectrometer, plasma detector, micrometeorite detectors, magnetometer, electron spectrometer, and scintillation gamma spectrometer.[104] It is not clear if this would still be the proposed instrument complement.

At the end of 1988, Soviet scientists reportedly again were discussing lunar probes, proposing the orbiter mission for 1992 and the far-side sample return for 1996.[105]

Asteroids

The Space Future Forum list included the VESTA mission with a 1994 launch date. This proposed program has changed several

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[101] Ibid.

[102] Moscow World Service, 2231 GMT, Feb. 19, 1987.

[103] Covault, Craig. Soviets in Houston Reveal New Lunar, Mars, Asteroid Flights. Aviation Week and Space Technology, Apr. 1, 1985. p. 18–19.

[104] Soviets in Houston Reveal New Lunar, Mars, Asteroid Flights. Aviation Week and Space Technology, Apr. 1, 1985. p. 19.

[105] Soviets Revise Mars Program; Prepare Missions to Moon. Aviation Week and Space Technology, Jan. 2, 1989. p. 39.

times since it was first raised by the Soviets. Originally listed as a potential mission by the Soviets in 1985, it was described as a probe that would be launched in 1991 and fly by Venus, then proceed on to study Vesta, one of the largest and brightest asteroids.[106] The proposal then changed to a probe that would go to Mars, and then to Vesta. The Forum paper listed both as alternatives. The main objective is not to study either Venus or Mars, but the asteroids, and the Forum paper stated that such a probe could land on an asteroid and possibly return a sample to Earth. As noted earlier, however, the Soviets stressed that this mission depended greatly on CNES and ESA decisions about building an asteroid module. If the mission is pursued, the Soviets suggested the following instruments: a high resolution, narrow angle camera and a wide angle camera; an infrared spectrometer; a radar; an ultraviolet spectrometer; a zodiac light detector; a dust detector; a mass meter; and a penetrator with an alpha backscattering spectrometer, an x-ray spectrometer, a TV camera, and detectors to study mechanical characteristics of the surface.

Outer Planets

The Moscow Space Future Forum paper included one of the first indications that the Soviets are interested in sending probes to the outer planets. They have never attempted to do so in the past. In the Forum paper, they listed a 1995 Corona Project to study Jupiter, and an unnamed 1999 probe to study Jupiter, Saturn and Titan (one of Saturn's moons) using a lander and balloon. Although the Forum paper did list types of instruments to be carried and objectives to be met, these missions are so speculative that the information will not be repeated here.

U.S./SOVIET COOPERATION

As already noted, the Soviet space science program is becoming increasingly internationalized. Although their first overtures outside the Soviet bloc have been to the Europeans, the strong interest in cooperating with the United States is also clear. Today, that interest is focussed on cooperative exploration of Mars, but joint working groups are involved in virtually every space science discipline. (This chapter discusses only automated space science programs, but it should be noted that the prospect of sending a joint U.S./Soviet human expedition to Mars has also received considerable attention. This topic is discussed in Part 1 of this study.)

The history of U.S./Soviet cooperative agreements will not be recapitulated here in detail.[107] The important point for the purpose

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[106] Covault, Craig. Soviets in Houston Reveal New Lunar, Mars, Asteroid Flights. Aviation Week and Space Technology, Apr. 1, 1985. p. 18-19.

[107] For a general review of U.S./Soviet space cooperation through 1987 and its relationship to future prospects for Mars cooperation, see: Smith, Marcia S. Space Cooperation Between the United States and the Soviet Union. Proceedings of the 30th Colloquium on the Law of Outer Space (Oct. 10-17, 1987). New York, American Institute of Aeronautics and Astronautics, 1988. For detailed information on cooperation prior to 1981, see previous editions of this report.

A detailed account of Soviet negotiating strategy for the 1987 agreement is given in: U.S. Congress. House. Committee on Foreign Affairs. Soviet Diplomacy and Negotiating Behavior: 1979-1988. Committee Print. 100th Cong., 2d Sess. Prepared by the Congressional Research Service. Washington, U.S. Govt. Print. Off., 1988.

of this report is that President Reagan chose not to renew the space cooperation agreement with the Soviet Union in 1982 because of concern about Soviet activity in Poland (two projects, one for search and rescue satellites and the other for a biosatellite mission, were "grandfathered," but other formal cooperation ceased). The United States attempted to renew cooperative activities in 1984, reiterating an earlier proposal to demonstrate crew rescue capabilities with a U.S. space shuttle/Soviet Salyut 7 space station mission. That fall, President Reagan signed into a law a bill calling for increased U.S./Soviet cooperation.[108] In the fall of 1985, a congressional delegation visited the Soviet Union to discuss potential cooperative missions, but to no avail.[109] The Soviets were not responsive to the U.S. overtures during this period because of their opposition to the U.S. Strategic Defense Initiative (SDI, or Star Wars) program for ballistic missile defense. Finally, in the summer of 1986, the Soviets decoupled their opposition to SDI from renewed cooperation in civilian space activities, and discussions began which led to a new five-year agreement being signed in April 1987.[110] The new agreement listed 16 areas of cooperation:

(1) Coordination of the Phobos, Vesta and [U.S.] Mars Observer missions and the exchange of scientific data resulting from them;

(2) Utilization of the U.S. Deep Space Network for position tracking of the Phobos and Vesta landers and subsequent exchange of scientific data;

(3) Invitation, by mutual agreement, of co-investigators' and/or interdisciplinary scientists' participation in the Mars Observer and Phobos and Vesta missions;

(4) Joint studies to identify the most promising landing site on Mars;

(5) Exchange of scientific data on the exploration of the Venusian surface;

(6) Exchange of scientific data on cosmic dust, meteorites and lunar materials;

(7) Exchange of scientific data in the field of radio astronomy;

(8) Exchange of scientific data in the fields of cosmic gamma-ray, X-ray and sub-millimeter astronomy;

(9) Exchange of scientific data and coordination of programs and investigations relative to studies of gamma ray burst data;

(10) Coordination of observations from solar terrestrial physics missions and the subsequent exchange of appropriate scientific data;

(11) Coordination of activities in the study of global changes of the natural environment;

(12) Cooperation in the Cosmos biosatellite program;

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[108] Cooperative East-West Ventures in Space. P.L. 98-562, October 30, 1984. Hearings were held on this bill in September 1984. See: U.S. Congress. Senate. Committee on Foreign Relations. East-West Cooperation in Outer Space. Hearing. 98th Congress, 2d session. September 13, 1984. Washington, U.S. Govt. Print. Off., 1984.

[109] See: U.S. Congress. House. Committee on Science and Technology. Visit to Sweden and the Soviet Union. Committee Print. 99th Congress, 1st Session. October 1985. Washington, U.S. Govt. Print. Off., 1986.

[110] Agreement Between the United States of America and the Union of Soviet Socialist Republics Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes. Signed April 15, 1987.

(13) Exchange of appropriate biomedical data from U.S. and U.S.S.R. manned space flights;

(14) Exchange of data arising from studies of space flight-induced changes of metabolism, including the metabolism of calcium, from both space flight and ground experiments;

(15) Exploration of the feasibility of joint fundamental and applied biomedical experiments on the ground and in various types of spacecraft, including exobiology; and

(16) Preparation and publication of a second amplified edition of the joint study "Fundamentals of Space Biology and Medicine."

The agreement established five working groups to deal with these issue areas, which have been meeting regularly since the agreement was signed. No new missions were included, since the availability of funding, at least in the United States, was considered doubtful.

At the 1988 Reagan-Gorbachev summit, the two countries slightly expanded their cooperative efforts. The following statement was included in the joint communique issued after the summit:

> Recognizing the long-standing commitment of both countries to space science and exploration, and noting the progress made under the 1987 U.S.–USSR Cooperative Agreement in the Exploration and Use of Outer Space for Peaceful Purposes, the two leaders agreed to a new initiative to expand civil space cooperation by exchanging flight opportunities for scientific instruments to fly on each other's spacecraft, and by exchanging results of independent national studies of future unmanned solar system exploration missions as a means of assessing prospects for further U.S.-Soviet cooperation on such missions. They also agreed to expand exchanges of space science data and of scientists, to enhance the scientific benefit that can be derived from the two countries' space research missions. They noted scientific missions to the Moon and Mars as areas of possible bilateral and international cooperation.[111]

One concrete result of these new agreements is the inclusion of a relay device on the U.S. Mars Observer spacecraft for use with the balloons that are to be included on the Soviet 1994 Mars mission.[112] However, the instrument would be supplied by France, rather than the Soviet Union.[113] Other candidate missions for exchange of experiments include: flying a U.S. Total Ozone Mapper Spectrometer (TOMS) on a Soviet Meteor weather satellite; installation of gamma ray burst detectors joint developed by the two countries on balloons launched in the Antarctic; and use of U.S.optics in a Danish x-ray telescope that will be flown on the Spectrum-Roentgen-Gamma mission.[114]

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[111] Joint Statement Between the United States and the Union of Soviet Socialist Republics Issued Following Meeting in Moscow, USSR, May 29–June 1, 1988. p. 14.

[112] U.S., Soviets Agree to Share Mars Exploration Data. Aerospace Daily, Nov. 14, 1988. p. 228.

[113] Lenorovitz, Jeffrey M. Soviets, U.S. Make Progress on Space Cooperation Talks. Aviation Week and Space Technology, Aug. 1, 1988. p. 43.

[114] Ibid.

A proposal that has received a lot of attention by both U.S.and Soviet scientists is for the two countries to cooperate in developing a rover/sample return mission.[115] Proposed by Roald Sagdeyev, the mission has received favorable responses from scientists and politicians who see it as an opportunity for the two countries to demonstrate that they can cooperate more in space. This type of mission, where each country would be responsible for building it own spacecraft, would limit technology transfer concerns since the only place the two spacecraft would have to have compatible systems would be for handing the samples collected by the rover to the spacecraft that would return those samples to Earth. It is expected that if this mission was pursued, the United States would build the rover, and the Soviets would build the sample return spacecraft.[116] This is not an approved project on either side of the Atlantic, however. NASA is performing studies of a Mars rover/sample return, but no decision has been made on actually designing vehicles. Meanwhile, scientists from both sides are discussing the options and how the work would be divided.[117]

The issue of potential technology transfer often is raised with regard to U.S./Soviet cooperation. In 1987, the NASA Advisory Council Task Force on International Relations in Space issued a report that addressed that issue, among others. The report concluded that after a "diligent" search, "no examples of NASA's cooperative activities leading to significant technology transfer" could be found, although they added that

> in working with NASA on the Apollo-Soyuz docking, it is reasonably alleged that the Soviets did learn much about how the United States manages large space programs. That is not to say that the Soviets have not had access to and acquired U.S. space technology to the disadvantage of U.S. national security, but that the major paths for Soviet acquisition of U.S. and Western technology are espionage, evasion of export controls and access to open literature . . . [P]lacing the onus on cooperation for undesirable technology transfer . . . is to miss the mark.[118]

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[115] See: U.S. National Commission on Space. Pioneering the Space Frontier. New York, Bantam Books, 1986. p. 162 and 164.

[116] Accept Soviet Offer of Joint Unmanned Mission to Mars: Edelson. Aerospace Daily, July 16, 1987. p. 82-3.

[117] Smith, Bruce A. Soviet Scientists Present Details of Mars Exploration Program. Aviation Week and Space Technology, May 25, 1987. p. 22.

[118] U.S. National Aeronautics and Space Administration. NASA Advisory Council. Task Force on International Relations in Space. International Space Policy for the 1990s and Beyond. Washington, NASA, Oct. 12, 1987. p. 27.

CHAPTER TWO ANNEX—SOVIET LUNAR EXPLORATION—AN ASTRONOMICAL PERSPECTIVE

Perhaps the greatest technological contest in history has been the drive into space by the United States and the Soviet Union. From Cape Canaveral, the Kennedy Space Center and Tyuratam the giant rockets have begun their thundering journeys bound for Earth orbit, the Moon, the planets and beyond.

The Moon, orbiting a quarter of a million miles from Earth, soon became a target symbolic of national power. Dollars and rubles by the billions were committed to its exploration. Tens of thousands of scientists, engineers, technicians and support personnel throughout the world forged a vision into the reality of flight—from the Earth to the Moon and back.

The Soviet Program

Many aspects of the Soviet lunar programs have remained shrouded in secrecy even though the actual flights took place nearly 2 decades ago. In general the goals of those missions which failed were never revealed. Successful missions, on the other hand, were widely publicized and so we have a fair amount of data with which to assess the overall goals of the Soviet program. Based on chronology and the different boosters used it has become common practice to discuss the three generations of Soviet lunar exploration.

FIRST GENERATION

On January 2, 1959, the first announced Soviet lunar probe, Luna 1, passed between five and six thousand km ahead of the Moon and entered an orbit about the Sun. It was boosted on a direct ascent trajectory from Tyuratam using the A-1 booster. This booster was similar to the A-vehicle used to launch Sputnik 1, except that an upper stage was added for lunar missions. The fall of 1959 saw Luna 2 score a bullseye strike on the Moon and also the spectacular flight of Luna 3 which obtained the first photographs of the far side of the Moon. The first generation of launches ended with Luna 3.

SECOND GENERATION

The second generation flight program did not begin until 1963 and continued until 1968 using the original A-vehicle topped with an improved upper stage. The A-2-e rocket payload of some 1500 kg was first placed into an Earth orbit and then launched toward the Moon. After at least seven failures, Luna 9 became the first spacecraft from Earth to soft land on the lunar surface. During early February of 1966 it transmitted 27 pictures back to Earth. By contrast the first American soft lander, Surveyor 1, landed five

months later and transmitted 11,237 pictures. In April 1966 Luna 10 became the first probe to enter lunar orbit, arriving five months ahead of the U.S. Lunar Orbiter 1. Other second generation probes photographed the surface and mapped out anomalies in the Moon's gravitational field.

Just three months after the Apollo fire, the Soviet Union's new Soyuz spacecraft was launched into Earth orbit piloted by Colonel Vladimir Komarov. He died while trying to land following a trouble plagued flight. The Soyuz was designed to carry a crew of three for Earth orbital flight and a variant of Soyuz called Zond was flown numerous times on automated circumlunar missions.

THIRD GENERATION

A powerful new booster began flight testing in 1965 and on March 2, 1968, the D-1-e or Proton vehicle was used to launch Zond 4 on an engineering flight test reminiscent of the Apollo 4/ Saturn 501 flight of November 1967. All third generation Soviet lunar flights rode on the Proton booster which had a thrust less than one third that of the giant Saturn V booster used for the American Apollo program.

During October 1968 a Soyuz spacecraft flew with a one man crew for the first time since the disaster of 1967. In both September and November of 1968 the Soyuz, in its Zond configuration, flew apparently successful unmanned circumlunar missions. A Zond launch window opened between December 8 and 10. Many Western observers expected that a single cosmonaut would be launched onboard Zond for a flight around the Moon, but the mission did not occur. Reports of Soviet launch failures indicated that there were lunar related launch attempts on April 15 and June 14, 1969.

Three days before the launch of Apollo 11, Luna 15 lifted off from Tyuratam and headed for the Moon. As the crew of Apollo 11 explored the lunar surface, Luna 15 crashed at 300 miles per hour into the Sea of Crises. Its mission was never announced.

The third generation flight program continued through 1976. During this time there were four types of lunar probes launched by the Proton booster.

(1) *Sample Returner*—Robot soft landing platforms capable of drilling into the lunar surface and then rocketing a soil sample back to Earth;

(2) *Lunokhod*—Robot roving vehicles under radio control from Earth used to explore the lunar surface;

(3) *Orbiter*—Primarily lunar photographic flights; and

(4) *Zond*—A series of circumlunar flight tests designed to perfect a complex Earth atmospheric skip reentry technique.

While many of these Soviet lunar missions were successful, there were also launch failures, lunar probes stranded in Earth orbit, and crashes on the lunar surface. What were these missions and how did they fit into the overall Soviet program? Was there a race to land men on the Moon or did the Russians plan to only use robot explorers as they now claim? In the months before the flight of Apollo 11, Soviet flight preparations were intense. There were rumors of launch failures associated with automated probes and

the continuing expectation that a Soviet piloted flight might still materialize.

The purpose of this paper is to examine the successful third generation Soviet lunar flights in terms of the geometry of the Sun-Earth-Moon system in order to understand the launch window constraints within which the Russians were forced to operate. This information will provide the basis for examining the failures and rumored launch attempts. The goal is to fill in a few more details of the great race to the Moon.

Coordinate Systems

The location of a celestial object most often is described in the equatorial coordinate system where the Earth's equator is the plane of reference. This spherical system has as its coordinates declination and right ascension. Declination is measured north or south of the equator and may be thought of as terrestrial latitude projected outward onto the celestial sphere. East-West location with respect to a reference point, called the vernal equinox, is given by right ascension. For the purposes of this paper, however, it will be more useful to talk about the age of the Moon rather than its right ascension.

LUNAR AGE

When the Moon lies between the Sun and the Earth, along the Sun-Earth line, it is called a new Moon. As time passes, the Moon moves eastward in its orbit around the Earth taking approximately 29.6 days to complete one revolution. Each revolution starting at new Moon is called a lunation and is identified by a lunation number. For example lunation #566 began when the Moon was new on September 22, 1968, at 1100 GMT.

The location of the Moon in its orbit is described by its age which is the number of days that have elapsed since the last new Moon. As viewed from the Earth the Moon exhibits different phases depending on its age. This is shown in figure 7.

LAUNCH TIME VS. AGE

For the time being we will ignore declination and consider what effect the age of the Moon should have on the launch time of a lunar probe. The problem is analogous to riding on a merry-go-round and trying to shoot outward at a target moving around the center in a large circle. Your seat on the merry-go-round corresponds to the longitude of the launch site on the Earth. You have to wait till the merry-go-round has turned to the right position in order to shoot radially outward at the target. At the time of launch the position of the Moon in its orbit is given by its age and the rotational position of the Earth is conveniently represented by the local time at the Greenwich meridian. One would expect a simple linear relationship to exist between launch time and lunar age and this is exactly the result which we get as shown in figure 8. Any Soviet lunar launch with a four day flight time from Tyuratam must fall on this line. Launches from a site at a different longitude would lie along a parallel line. Additional data about these Soviet launches is given in table 6.

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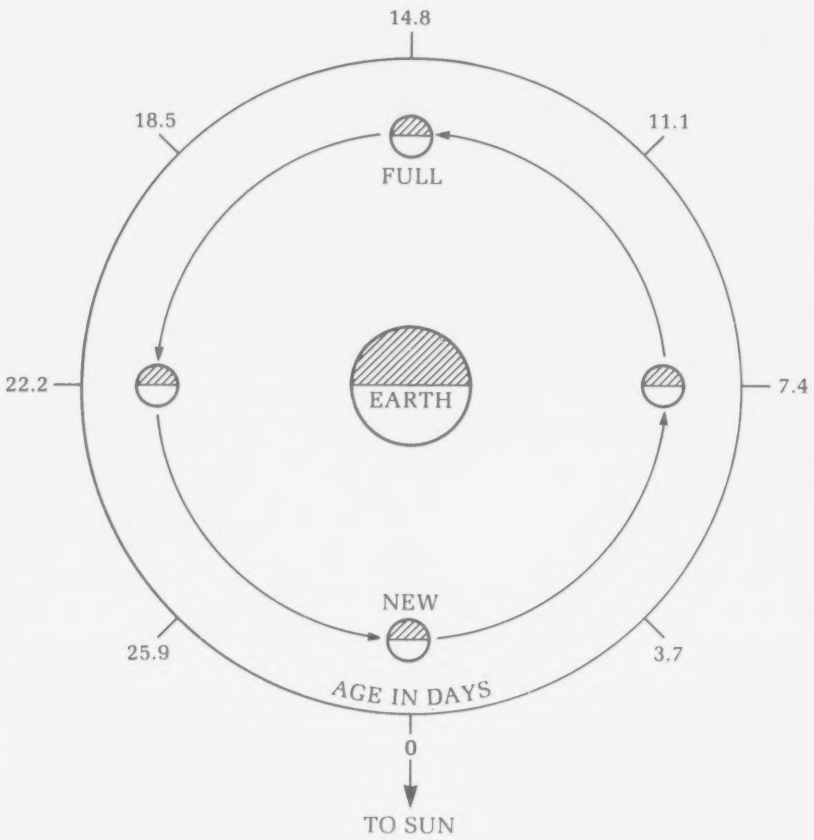
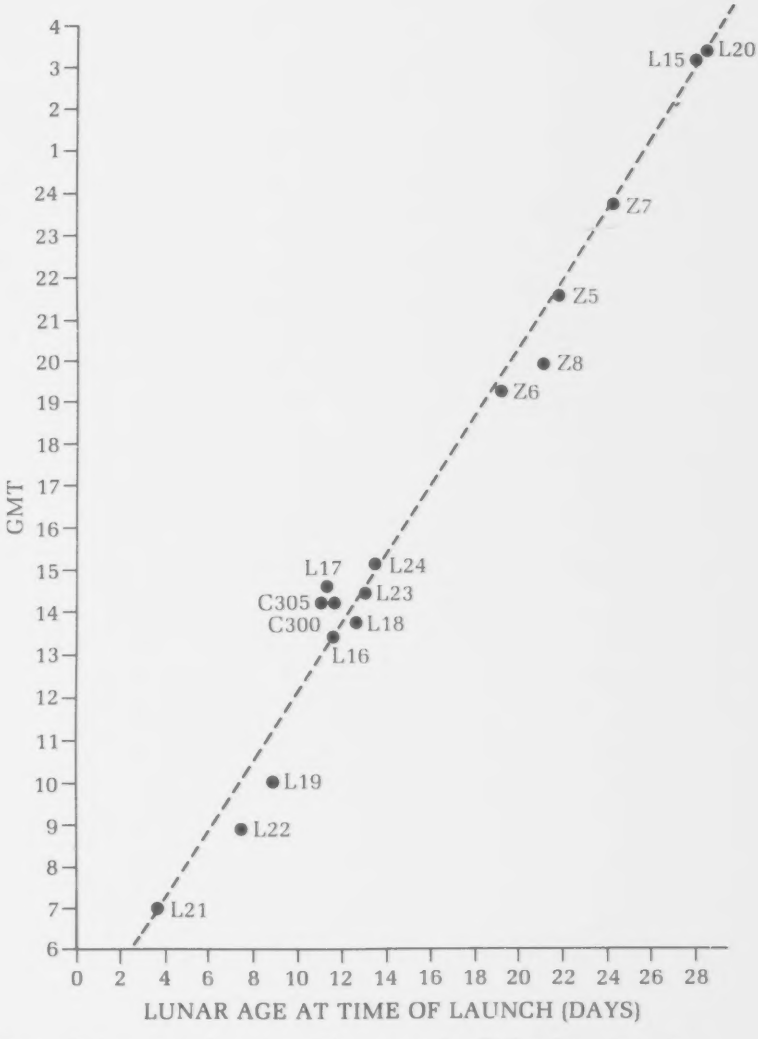
Figure 7.—Lighting Conditions as a Function of Lunar Age



The night hemispheres of the Earth and Moon are shaded.

By R.S. Flagg

Figure 8.—Lunar Age at Time of Launch (Days)



Launch times as a function of lunar age for flights from Tyuratam.

By R.S. Flagg

TABLE 6.—SOVIET LUNAR PROBES: 1968–1976

Mission	Type	Launch Date	Time (GMT)	Lunation	Age (Days)	Dec. Phase (Deg)
Zond 5	CLRT	Sep. 12, 1968	2140	565	21.9	81
Zond 6	CLRT	Nov. 10, 1968	1912	567	19.9	108
	X	Apr. 15, 1969		572		
	X	Jun. 14, 1969		575		
Luna 15	X	Jul. 13, 1969	0300	575	28.1	96
Zond 7	CLRT	Aug. 07, 1969	2346	576	24.4	79
C.300	X	Sep. 23, 1969	1410	578	11.8	330
C.305	X	Oct. 22, 1969	1410	579	11.2	353
Luna 16	SR	Sep. 12, 1970	1326	590	11.7	314
Zond 8	CLRT	Oct. 20, 1970	1955	591	20.2	107
Luna 17	ROV	Nov. 10, 1970	1440	592	11.3	16
Luna 18	SR	Sep. 02, 1971	1350	602	12.6	312
Luna 19	ORB	Sep. 28, 1971	1000	603	8.8	290
Luna 20	SR	Feb. 14, 1972	0328	607	28.6	322
Luna 21	ROV	Jan. 08, 1973	0655	619	3.6	341
Luna 22	ORB	May 29, 1974	0857	636	7.5	181
Luna 23	SR	Oct. 28, 1974	1430	641	13.1	17
Luna 24	SR	Aug. 09, 1976	1504	663	13.5	321

Soviet launches including successful missions and some reported failures. The types are: CLRT—circumlunar return; X—failure; ROV—lunar roving vehicle; SR—sample returner. Prepared by R.S. Flagg.

DECLINATION

The Earth's orbit around the Sun lies in the ecliptic plane. The Earth's rotation axis is inclined, or tilted, 23.5 degrees from a perpendicular to the ecliptic and this causes the Sun's yearly motion above and below the equator. At local noon, near June 21st, the Sun is directly overhead at 23.5 deg. north latitude while six months later it has moved an equal distance into the southern hemisphere. While it takes a year for the Sun to cycle through its range of declinations, the Moon does so in a month which is the time it takes to go around the Earth.

The orbit of the Moon is inclined five degrees to the ecliptic plane. Because of this tilt there are two points called nodes where the Moon's orbit intersects the ecliptic. The nodal points precess, or drift, around the Earth every 18 years and consequently every 18 years the Earth's axial tilt and the Moon's orbital inclination combine to produce a maximum monthly swing in the Moon's declination. At this time the lunar declination will vary between the extreme values of 28.5 degrees north and south. Nine years, or half a cycle later, the effect is to produce a minimum variation in the monthly declination range which then becomes 18.5 degrees north and south.

DECLINATION PHASE

Each month as the Moon orbits the Earth its declination varies in a near-sinusoidal manner as shown in figure 9A. As we have seen the maximum declination reached each month is not constant and can vary by 10 degrees over the course of several years. This is shown in figure 9B where declination plots for two different months are given. The plots have been aligned in phase and a new variable termed declination phase ($d\Phi$) has been introduced as a

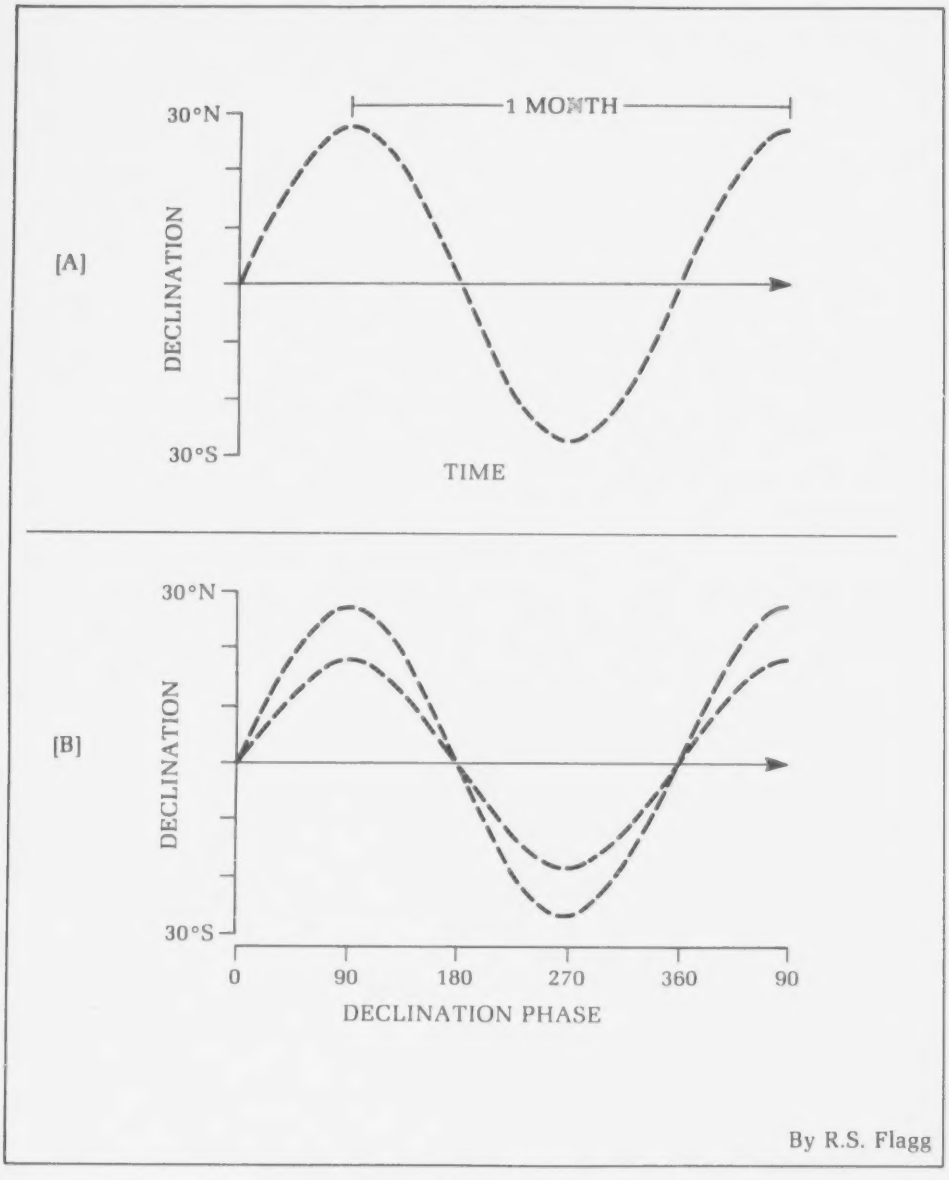
measure of time. Because of the cyclic variation in declination each month the maximum northern value of declination is reached when $d\Phi = 90$ degrees and the maximum southern declination is reached when $d\Phi = 270$ degrees, regardless of the maximum monthly swing in declination. Declination phase which varies from 0 to 360 degrees serves as a normalized representation of lunar declination and allows the comparison of lunar flights occurring years apart when the monthly maximum declination values were significantly different.

AGE VS. DECLINATION PHASE PLANE

The Moon's location may be specified in terms of the two variables; age (A) and declination phase ($d\Phi$). A plot of the Moon's motion on the A,$d\Phi$ plane during a typical lunation is shown in figure 10.

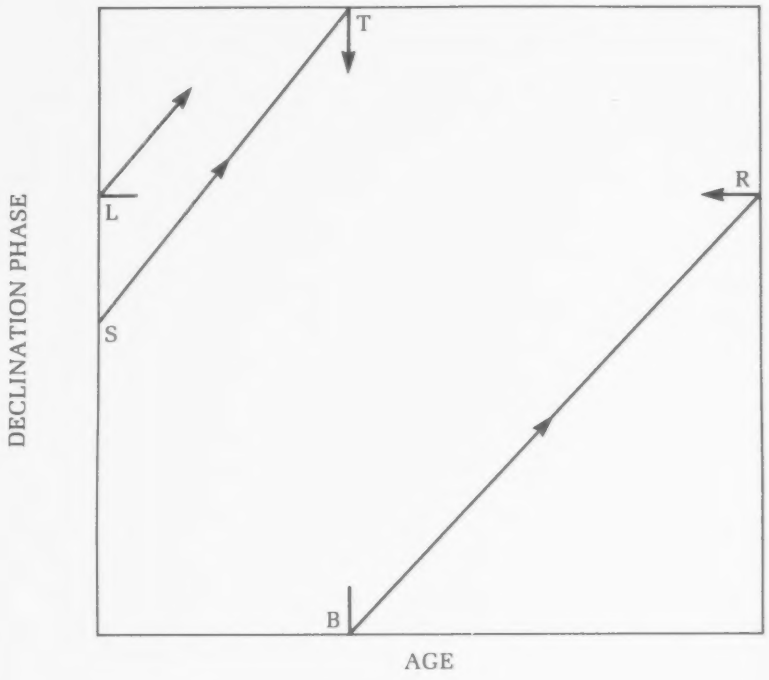
The trajectory of the Moon on the A,$d\Phi$ plane is not the same for all lunations. In general, every lunation follows a parallel but different track. If all lunations for several years are plotted then the whole area of the A,$d\Phi$ plane becomes filled.

Figures 9A and 9B—Relationship Between Declination, Time and Declination Phase



By R.S. Flagg

Figure 10—Moon's Motion for a Typical Lunation



The moon's motion is shown for a typical lunation on the A, $\delta\phi$ plane. Note that $\delta\phi$ equals 180 degrees at both top and bottom while A equals 0 days at both the left and right boundaries. This lunation begins at (S) with the moon following the trajectory S-T-B-R-L. Point (L) occurs 29.6 days after (S).

By R.S. Flagg

The eleven lunations occurring between August 24, 1968, and August 13, 1969, are shown in figure 11. The plot begins in the upper left hand corner with L #565 (00h GMT August 24, 1968) and continuously depicts A,$d\Phi$ values through the end of L #576 (13h05m GMT August 13, 1969). The position of the Moon at the launch time for each of the Soviet lunar flights which occurred during this period of time is also shown.

Soviet Flights Mapped on the (A,$d\Phi$) Plane

Between 1968 and 1976 Soviet lunar exploration programs such as the sample returners, Lunokhod, lunar orbiters and Zond were flown using the Proton launch vehicle. Many unsuccessful lunar related launch attempts also have been reported or rumored and several of these as well as the successful flights have been summarized in table 6.

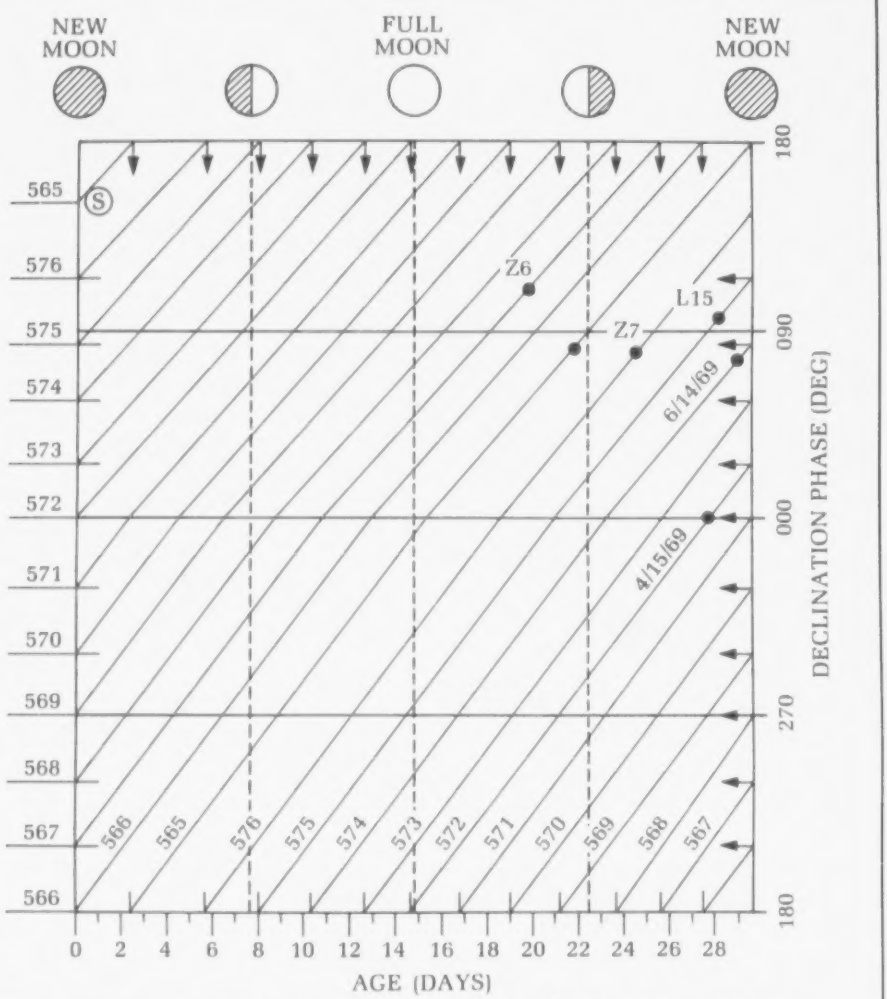
Using data from the *American Ephemeris and National Almanac* (A,$d\Phi$) maps have been generated spanning the years of Soviet lunar exploration. Using these maps the location of the Moon at the launch time of each successful flight has been determined. These data are shown in figure 12.

It is seen that the various mission types tend to fall into groups such as the Zonds in the upper right and the sample returners (Luna 16, Luna 24) slightly below and to the left of center. Based on these groupings, we can tentatively define areas on the A,$d\Phi$ plane associated with the different types of missions. These areas are shown in figure 13. The boundaries of each area are located at two standard deviations (2-sigma) from the center obtained by averaging in both age and declination phase. Of course the statistical sample available for each mission type is extremely small and consequently the area boundary locations are approximate at best. None the less, it appears possible to characterize, at least in a preliminary way, the different mission types in terms of their locations on the A,$d\Phi$ plane.

(A) Sample return launches occur in either of two windows separated by half a month in lunar age. Both windows show a preferred declination phase of 316 degrees.

(B) Lunar orbiter launches show little dependence on $d\Phi$ but do occur close to an age of 8.1 days. This is very similar to the second generation Lunas 4–14 which were all launched near an age of 8.9 days.

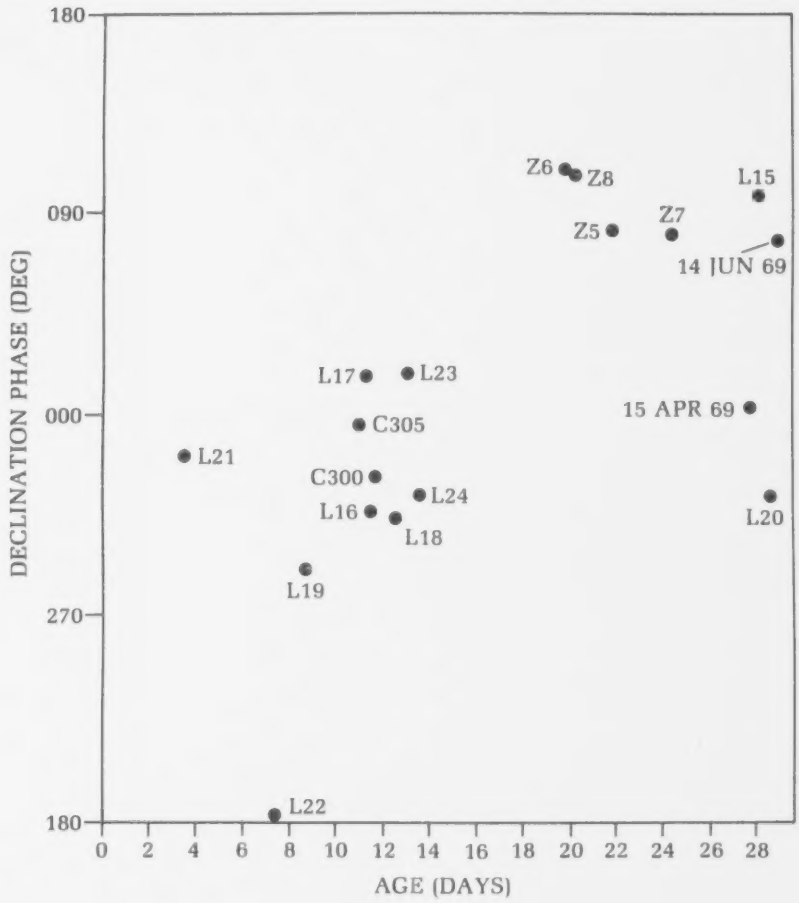
Figure 11.—Moon's Location for Lunations 565–576



The moon's location is depicted on the A,δϕ plane for Lunations 565-576. The beginning of Lunation 565 which is shown as point (S) in the upper left hand corner occurred August 24, 1968 at 0 hours GMT. The location of the moon is shown for three Zond flights, Luna 15 and for two reported failures.

By R.S. Flagg

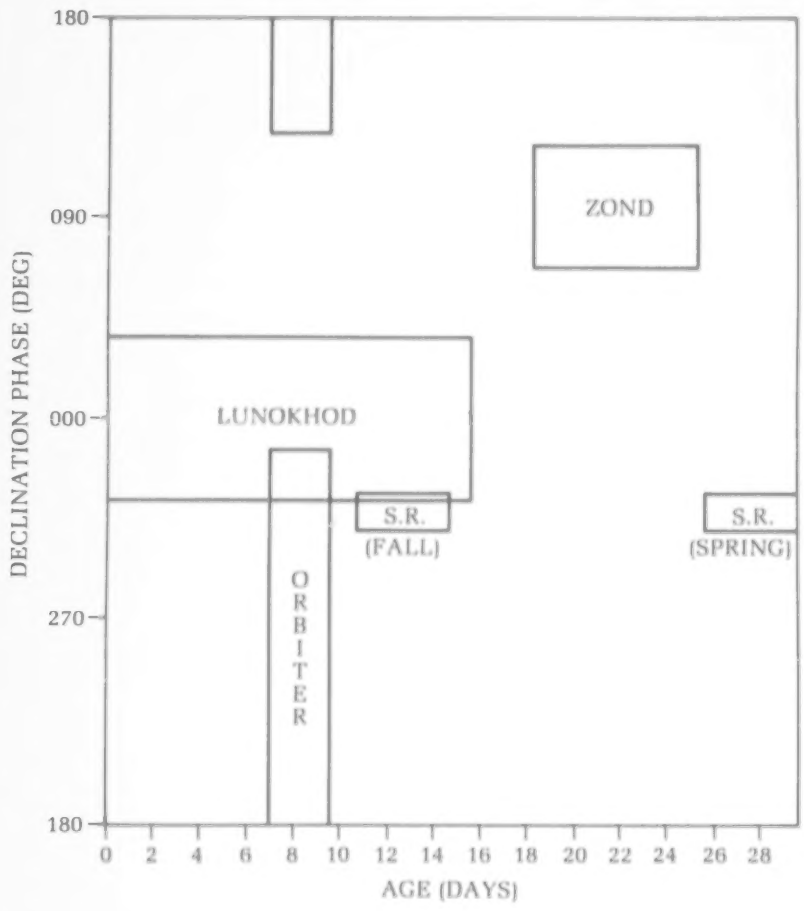
Figure 12.—Moon's Location at Time of Soviet Missions



Successful flights and reported launch failures plotted on the A,$\delta\phi$ plane.

By R.S. Flagg

Figure 13.—Soviet Lunar Mission Groups



Two-sigma boundary locations on the A,$\delta\phi$ plane for the different mission types.

By R.S. Flagg

(C) The Zond circumlunar flights appear isolated from the other mission types and were launched shortly before new Moon.

It is apparent from figure 13 that it will be difficult if not impossible to differentiate between an unsuccessful Orbiter, Lunokhod or sample-returner in that region of the A,$d\Phi$ plane where all three mission types overlap. Had there been more flights of each type, more meaningful boundaries would have resulted from the improved statistics. This was not the case and so we must look for the underlying launch constraints that have produced the observed grouping of the different mission types. When these physical and geometric constraints are understood it will be possible to define launch window boundaries with some improved degree of confidence.

In the next section we investigate flight durations, landing locations and lighting conditions for those probes which reached the Moon.

FLIGHT DURATIONS

The flight time from Earth to entry into lunar orbit for the Luna series was 4.4 days while the faster Zond spacecraft reached the Moon in 3.2 days. Since the Moon moves 13 degrees eastward in its orbit each day, the aiming point for a Luna was approximately 57 degrees eastward of the Moon's position at the time of launch. During the 4.4 day flight time, both the vehicle and the Moon travel along their respective orbits toward the intersection. The corresponding aiming point for the Zonds was 42 degrees ahead of the Moon.

LUNAR LONGITUDE

Locations on the Moon are defined by a system of latitude and longitude similar to the familiar system used on Earth. On Earth the eastern and western hemispheres are separated by the "prime Meridian" which runs through the poles and Greenwich, England. The prime meridian of the lunar longitude system runs north and south through the center of the visible disc and is always facing toward the Earth. The reason for this is that it takes a month for the Moon to complete one rotation about its axis. During this time the Moon also revolves completely around the Earth. The effect is to keep the same face toward the Earth. It is local midnight on the prime meridian at the time of new Moon and local noon at the same location 14 days later when the Moon has moved halfway around its orbit.

LANDING GEOMETRY

Figure 14 shows the location of the Moon in its orbit at the time of landing for each probe. The Earth is located in the center of each diagram. The Moon has been shaded to show its dark and sunlit hemispheres. Vectors (S) point to the Sun from both the center of the Earth and from the probe landing site, while vector (V) points in the direction of the local vertical at the landing site. Angle (A) is the lunar age expressed in degrees while (L) is the landing longitude and (B) is the angle between the local vertical (V) and the Sun (S).

All eight third generation spacecraft which reached the lunar surface are shown in this figure. Lunas 16, 20, and 24 were successful Sample Returners. The true mission of Luna 15 was never announced by the Soviets, while 18 and 23 were reported to be Sample Returners which failed to survive their landings.

From figure 14 we see that Lunas 16, 18, 23 and 24 all landed in darkness near 58 degrees east longitude. While Lunas 15 and 20 also landed near 58 degrees east they did so at a time of the month when this location was in sunlight. After approximately one day on the surface, Lunas 16, 20 and 24 began the return journey to Earth. It is interesting that the return flight paths were nearly at right angles to the Earth-Sun line. Perhaps this geometry was desirable for thermal control of the return module which could have been put into a "barbecue mode" by simply imparting rotation about the roll axis. Such rotation also would have the effect of spin stabilizing the return module.

Lunas 18 and 23 both landed near 57 degrees east and would have followed similar trajectories if they had departed after one day on the surface. These geometric similarities lend credibility to the Soviet reports that both spacecraft were sample returners.

Lighting and landing geometry was nearly identical for Lunas 15 and 20 which strongly suggests that Luna 15 was also a sample-return mission.

It appears that an important constraint placed upon the Earth launch of a sample return mission was that some nine days later the return trajectory would be nearly perpendicular to the Earth-Sun line. This meant that when the return module was launched the Moon was near first quarter (Luna 20) or third quarter (Lunas 16 and 24). Since the return trajectory constraint could be met twice each month, we see two launch areas on the (A,$d\Phi$) plane separated by half a month.

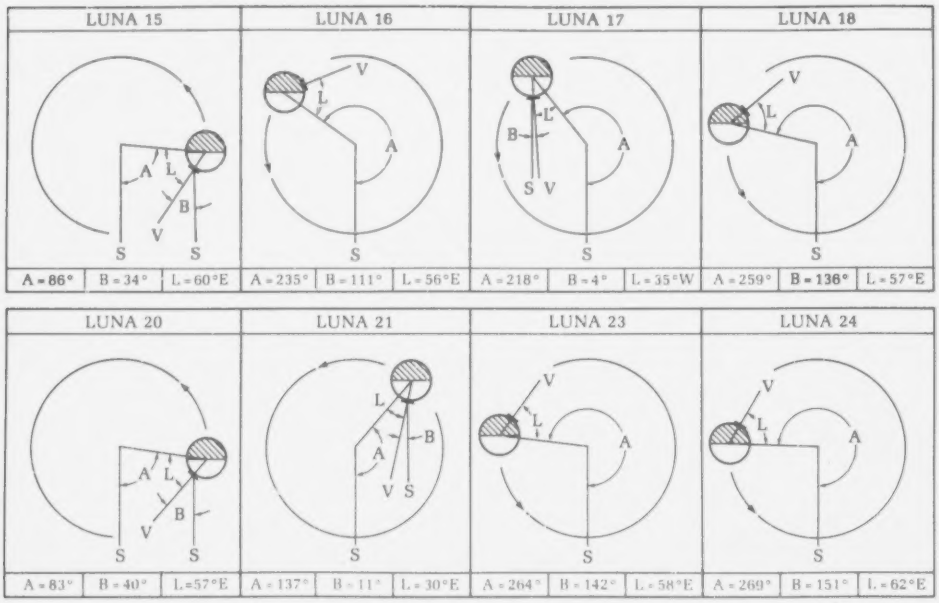
LUNOKHOD

The landing geometry and lighting conditions targeted for the two Lunokhod roving vehicles (Lunas 17 and 21) were markedly different than for the sample returners. The most striking similarity between the two Lunokhods is that both touched down near local noon, that is with the Sun close to overhead at the landing longitude. Presumably this was necessary in order to insure maximum rate battery charging from the solar cell array shortly after landing.

The constraint of landing on the Moon near the local noon longitude determines at what time during a lunation a Lunokhod landing can be made at any particular lunar longitude. The geometry is depicted in figure 15A. If a Lunokhod were targeted for 0 degrees longitude then it would land at full Moon. If, on the other hand, the target longitude was 90 degrees east then the landing would take place at first quarter Moon.

A plot of lunar age vs. longitude of local noon is given in figure 15B. Data points for Lunas 17 and 21 are shown on this plot. The coordinates of the data points are the landing longitude and the age of the Moon at the time of touchdown. Both points fall very close to the theoretical line.

Figure 14.—Moon's Location at Time of Luna Landings



Lighting angles and landing locations for those third generation spacecraft which reached the surface of the moon.

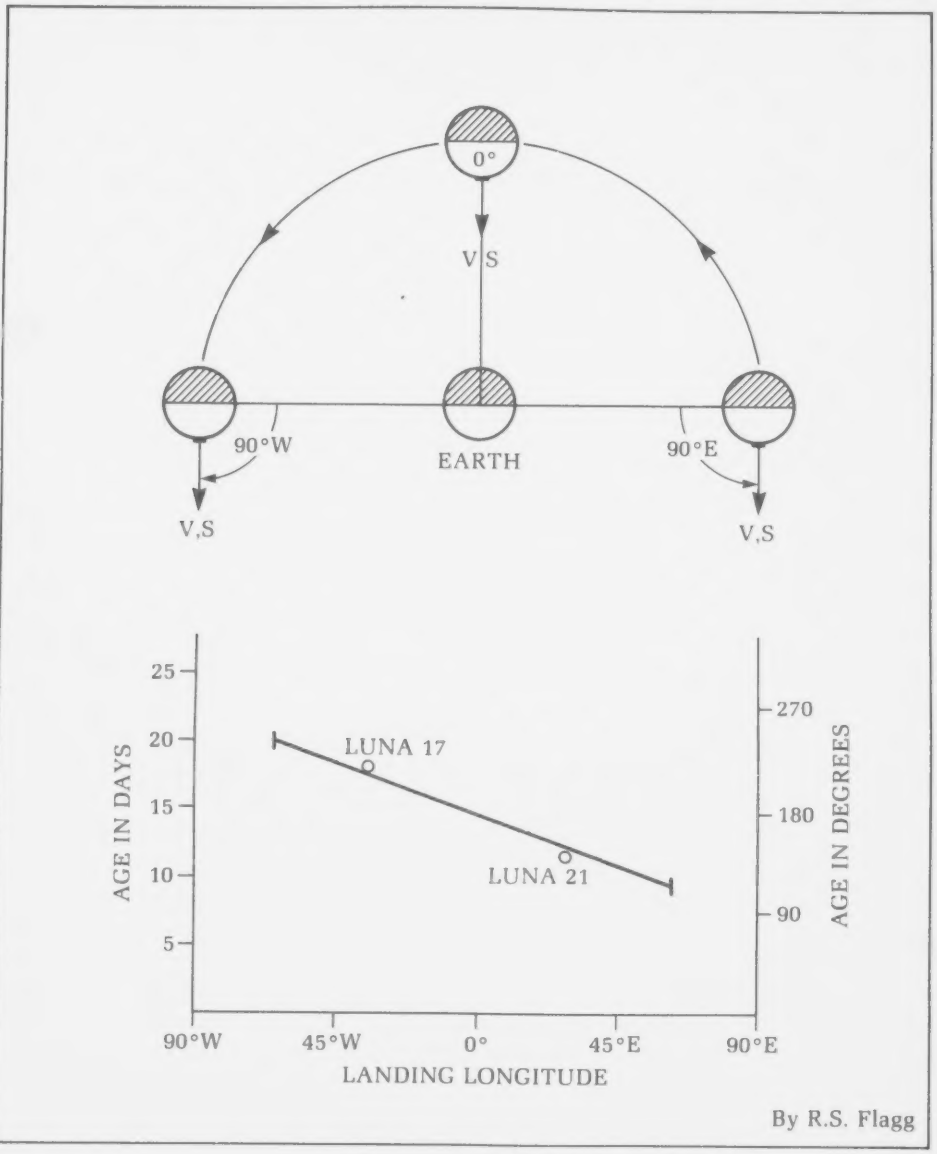
By R.S. Flagg

A landing would have to occur between 90 degrees east and 90 degrees west for the Lunokhod to be in view of the Earth. This range of lunar longitudes defines the front side of the Moon (excluding the effects of libration). If the landing occurred at either of these extreme longitudes then the Earth would be right on the horizon as seen from the Lunokhod and communications could easily be blocked by any mountains. In order to maintain reliable communication, the Earth would have to be several degrees above the horizon. We shall assume for this study that landing longitudes were chosen which put the Earth at least 25 degrees above the local horizontal. This means that a landing would not have been attempted at a more extreme lunar longitude than 65 degrees.

From figure 15B we see that a 65 degree east landing would occur at an age of 9.5 days and a 65 degree west landing 20 days. If we take the average mission elapsed time at landing of 7 days, then a Lunokhod launch could only occur when the age of the Moon was between 2.5 and 13 days.

Up to this point we have analyzed successful launches on the A,$d\Phi$ plane and also seen the landing geometry and lighting conditions for all third generation probes which touched down on the Moon. The age of the Moon has been shown to be an important factor in determining the launch times of both the Lunokhods and sample-returners. It seems that lighting conditions also may have been important for Zond launches as they were scheduled to arrive near the time of new Moon when the far side was illuminated.

Figures 15A and 15B.—Lunar Landing Longitude of the Lunokhod Vehicles as Related to the Age of the Moon



Before taking a closer look at the Zond missions we will consider some of the aspects of the trajectories required to get from the Earth to the Moon.

THE LUNAR TRAJECTORY

In order to explain the trajectory taken by a lunar probe, it will be helpful to begin with a simplified model. Consider a non-rotating Earth with its equator in the ecliptic plane. The Moon will orbit the Earth in the ecliptic plane and the probe will be launched from a polar parking orbit. This geometry is seen from the plane of the equator in figure 16A.

The probe is launched due south into its parking orbit. A little more than halfway through the first orbit the trans-lunar injection (TLI) burn is made with the probe heading northward over the equator. The TLI burn changes the circular parking orbit into a highly elliptical transfer orbit with apogee at the distance of the Moon's orbit on the opposite side of the Earth from the TLI burn point. The plane of the transfer ellipse is at right angles to the plane of the Moon's orbit and consequently if the probe were to go into lunar orbit, it would be a polar orbit inclined 90 degrees to the Moon's equator.

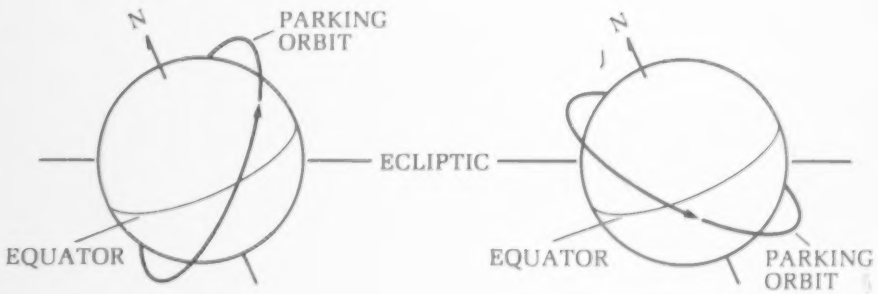
To hit a particular target point along the Moon's orbit requires that the probe be launched at the correct time during the Earth's daily rotation. The target point and the orientation of the transfer orbit become fixed in space at the time of launch although the Earth continues to rotate inside the stationary orbital plane.

The Moon moves over 2,000 miles/hour in its orbit and the flight time of a lunar probe is about four days. In order for the probe to intercept the Moon, the target point must lead the Moon by 192,000 miles.

Before leaving the simplified model an additional term will be defined. The opening angle, theta, is measured between the plane of the Moon's orbit and the plane of the transfer orbit. In our example theta was 90 degrees. If the probe had been launched from an equatorial parking orbit then the opening angle would have been 0 degrees. In actuality the Earth's axis is tilted 23.5 degrees and probes are launched from parking orbits inclined to the equator. The result is that the opening angle is not constant but in fact varies as the Earth turns.

Figures 16A, 16B and 16C.—Orbital Relationships

[A]



[B] [C]

The geometric relationship between the ecliptic, equator, parking orbit and the transfer orbit with the opening angle measured between the ecliptic plane and the plane of the transfer orbit.

By R.S. Flagg

Proton boosters carrying lunar payloads are launched toward the northeast from Tyuratam, with the spacecraft injected into an Earth parking orbit inclined 51.7 degrees to the equator. A little more than one hour after launch the probe is heading in a northeasterly direction across the South Atlantic. It is at this point where the TLI burn is made.

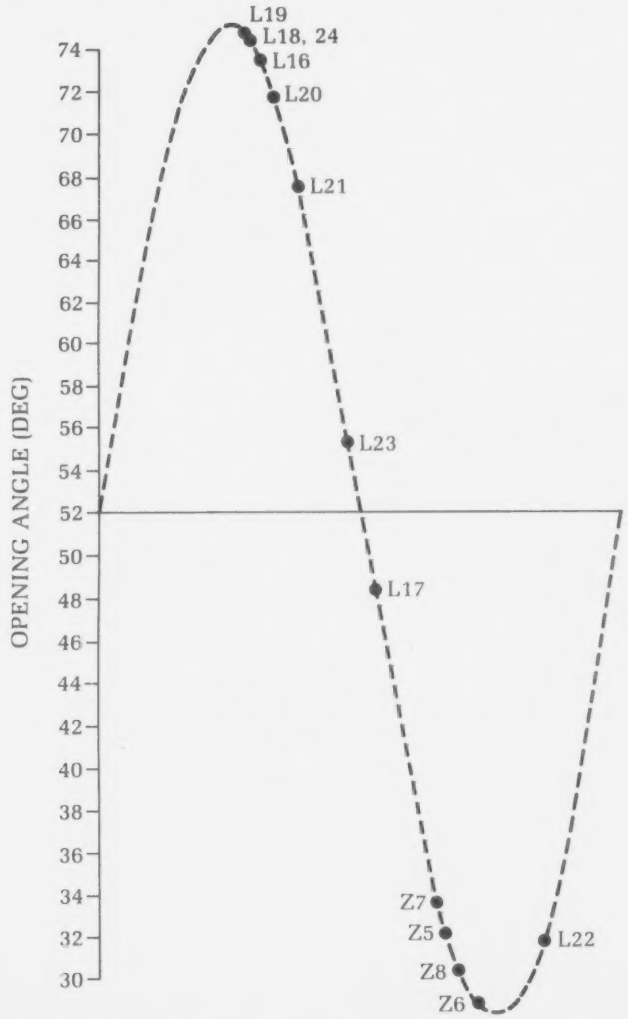
The parking orbit and its orientation with respect to the equator and the ecliptic is depicted in figure 16B. At the particular time shown the opening angle is a maximum of 75.2 degrees. If the launch had occurred twelve hours, or half a revolution of the Earth, later then theta would be at the minimum value of 28.2 degrees, as seen in figure 16C. During the daily rotation of the Earth the opening angle oscillates between the extreme values of 28.2 and 75.2 degrees. When theta is 28.2 degrees the transfer orbit is as close as it will get to being in the same plane as the Moon's orbit. It is at this time that the Zond probes were launched. This is seen in figure 17 which is a plot of launch occurrence vs. opening angle. All Zond flights are seen to be tightly grouped near the minimum opening angle while the sample returner missions in general cluster about the maximum (the exceptions being Luna 15 and Lune 23).

ZOND

It appears that not only were age and declination phase important but that the Zonds had to be launched at a very restricted time when the parking orbit and the Moon's orbit were most nearly coplanar. This condition is examined in detail for Zond 5 with the aid of figure 18.

Several functions are plotted here. The plot depicts the age of the Moon, the age or location of the parking orbit target point and the magnitude of the opening angle for September 14, 1968, when Zond 5 was launched at 2136 GMT. The horizontal axis is time of day (GMT). The right side vertical axis is the magnitude of the opening angle. The left hand vertical axis corresponds to lunar age. The opening angle curve reaches a minimum at midnight for this particular date. The curve labeled TARGET indicates the parking orbit target point for a launch at any time between 16H and 24H GMT on the 14th of September. Zond 5 was targeted for a point 310 degrees past new Moon. At launch time the Moon was actually located at 266 degrees so the target point led the Moon's position by 44 degrees. During the 3.2 day outbound flight of the Zond the Moon moved 42 degrees, closing to within 2 degrees of the target point. As Zond neared the target point, its trajectory was altered by the lunar gravity so that it passed behind the Moon and emerged flying toward Earth.

Figure 17.—Lunar Missions as a Function of Opening Angle



Lunar missions plotted as a function of opening angle. The Zonds flew at times when the transfer orbit and the moon's orbit were most nearly coplanar.

By R.S. Flagg

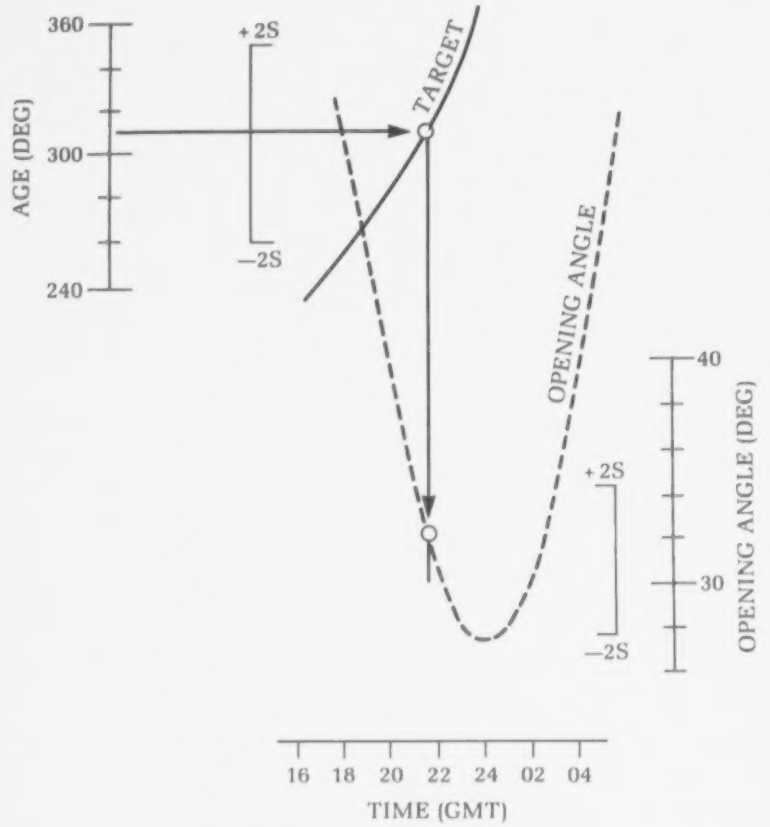
From figure 18 one can estimate the number of consecutive days available for the launch of Zond 5. To do this we must put bounds on the target point angle and the opening angle. These limits, shown as brackets, were obtained by calculating the 2-sigma ranges based on all four Zond flights. Only those launch opportunities falling within both the target point (266–355 degrees) and the opening angle limits are considered to be possible. For two days either side of September 14th the TARGET and the OPENING ANGLE curves for Zond 5 remain essentially fixed. However, the Moon itself moves some 13 degrees further around its orbit each day. On the 15th the Moon was at 279 degrees, therefore the target angle was 323 degrees which is well within the limits of 266–355 degrees. By projection from this angle off the TARGET curve, we find that the corresponding launch time was 2212 GMT and the opening angle was 31 degrees.

Use of this procedure for other days shows that for this particular lunation (#565), the launch window was open on five consecutive days, from the 13th through the 17th with the launch time some 36 minutes later each day.

Similar curves have been constructed for the period August 1968 through January 1969. From this data it appears that the 1968 Zond launch season opened August 18th with two consecutive days available during lunation #564. The last launch window was on the 9th of December and it was not until August of 1969 that another opportunity became available.

The Zond missions apparently could only fly trajectories that were close to coplanar with the Moon's orbit. The probable reason for this was to minimize the perturbing effects of lunar gravity. Had a Zond approached the Moon from a transfer orbit with a large opening angle, one effect of the Moon's gravitational field would have been to change the plane of the orbit, deflecting the probe from the desired return trajectory to Earth. By approaching the Moon close to its orbital plane, the out of plane gravitational component is reduced, thus simplifying correction of trajectory perturbations. This constraint appears to have severely limited the number of Zond launch opportunities.

Figure 18.—Zond 5 Orbital Relationships



The opening angle and parking orbit target point vary as the earth rotates. These functions are depicted for the launch of Zond 5.

By R.S. Flagg

THE A,$d\phi$ PLANE REVISITED

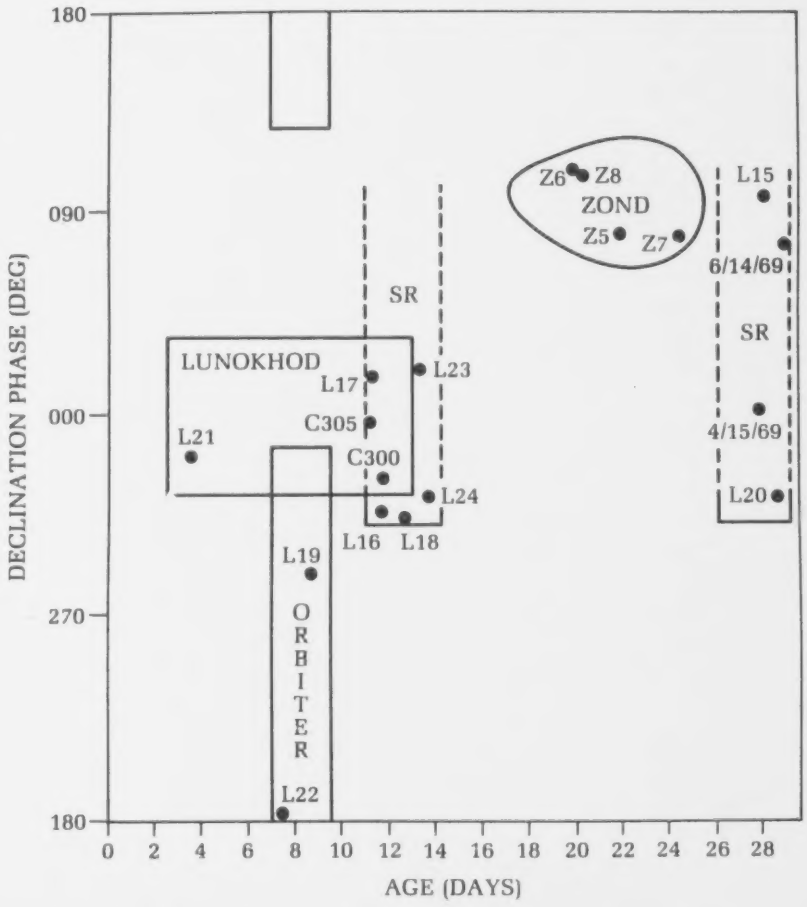
Earlier in this paper, launch areas or windows were plotted on the A,$d\Phi$ plane for the different mission types (see figure 13). This figure was plotted using the age and declination data from each successful flight to compute the 2-sigma boundaries. Now that the underlying geometric constraints have been defined, it is possible to establish more valid boundaries for the different mission launch areas. Figure 18 shows these refined boundaries and also the data points for all the successful Soviet lunar missions as well as many of the reported and rumored failures.

It is important to remember that it takes the Moon approximately one year to move throughout the area covered by the A,$d\Phi$ plane. Because of this the plot not only shows the Moon's location at any given time, but also depicts the chronological order in which the launch windows occurred. Figures 11 and 19 will be used together to develop the probable sequence of Soviet lunar launch attempts during 1969.

LUNAR MISSIONS (1969)

Lunation #569 began on December 19, 1968. Age, declination phase and opening angle values came close to permitting a Zond launch between January 7th and 9th, but were definitely outside those parameters as defined by the successful Zond flights. On the 18th of January 1969, lunation #570 began. Table 7 is a chronology of available launch windows for 1969 has been derived by noting the dates when A,$d\Phi$ values fell within the permitted ranges for each of the different mission types.

Figure 19.—Soviet Lunar Flights With Improved Mission Boundaries



Soviet lunar flights plotted on the A,δϕ plane with improved mission boundaries. The Sample Return boundaries have been expanded as shown by the dashed lines.

By R.S. Flagg

TABLE 7.—AVAILABLE LUNAR LAUNCH WINDOWS: 1969

Launch Window	Mission Type	Lunation Number
Jan 20–25	LKD	570
Feb 15–17	SR	570
Feb 18–21	LKD	571
Mar 14–17	SR	571
Apr 13–16	SR	572
May 12–15	SR	573
Jun 12–15	SR	574
Jul 11–14	SR	575
Aug 07–08	ZD	576
Aug 25–28	SR	577
Sep 03–07	ZD	577
Sep 22–24	LKD	578
Sep 22–25	SR	578
Sep 30–Oct 03	ZD	578
Oct 20–24	LKD	579
Oct 22–25	SR	579
Oct 29–Nov 01	ZD	579
Nov 16–21	LKD	580
Nov 20–23	SR	580
Nov 26–28	ZD	580
Dec 13–19	LKD	581

(Lunokhod = LKD, Sample Returner = SR and Zond = ZD.) Prepared by R.S. Flagg.

During the months preceding the successful flight of Apollo 11, rumors and reports of Soviet lunar flight attempts abounded in the press. It is difficult to assess the validity of these stories as they were the result of leaks either from the Western intelligence community or unofficial Soviet spokesmen. The Soviets have always attempted to hide their failures simply by not announcing cancelled countdowns or launch failures and resorting to the generic Cosmos label for spacecraft that malfunction upon reaching orbit. In general, the intelligence community does not release information concerning Soviet launches since such information could compromise the capabilities of their monitoring and detection systems. It is reasonable to expect that some of the reported launches did indeed take place, but that there may well have been other launch attempts that either resulted in cancelled countdowns or failures early in flight.

With this in mind, we will concentrate on the launch opportunities available to the Soviets in the first six months of 1969. Through July 14 there were 2 Lunokhod and six sample return windows. The Proton booster and the lunar descent stage were common to both mission types. Both mission types had separate and difficult technical obstacles to overcome once the payload had been delivered to the lunar surface by the descent stage. It is unknown which payload (the Lunokhod roving vehicle or the sample return capsule) reached flight status first. However, if the Lunokhod was ready to fly, then there were launch opportunities available in January and February. A period of five launch windows for sample returners occurred in consecutive months from March through July. During this time launch attempts were reported corresponding to the April 13–16 and June 12–15 windows. (See references 1,2,3,4,5). On July 13, Luna 15 began its journey from Tyura-

tam and entered lunar orbit four days later. It flew and maneuvered in orbit for four days and then on July 21, while the Apollo 11 crew was exploring the Sea of Tranquility, Luna 15 crashed in the Sea of Crises.

The attempts for a successful landing continued, with the flights of Cosmos 300 on September 23 and Cosmos 305 on October 22. Both probes failed to leave Earth orbit. Finally on September 12, 1970, Luna 16 was launched to become the first successful sample returner. Luna 17 followed less than a month later and explored the lunar surface under remote control for several months. During the next six years the Soviets continued a comprehensive program of lunar exploration. Lunas 18, 20, 23 and 24 were sample returners, Lunas 19 and 22 were orbiters and Luna 21 carried a second Lunokhod to the Moon. The Zond program continued after Apollo 11 with two more apparently successful robotic flights.

CONCLUSIONS

We have seen that the age and declination of the Moon as well as the orientation of the transfer orbit were all important factors in determining when lunar missions could be flown. The technique of mapping flights on the age-declination phase plane offers a successful method for discriminating between different types of flights. Based on this technique the following conclusions are drawn about individual flights and mission types.

(1) The launch of a sample returner was timed so that the return trajectory was approximately at right angles to the Sun-Earth line. Such a flight orientation would provide thermal control for a spin stabilized return module.

(2) Luna 15 appears to have been a sample return mission which was racing with Apollo 11 to return lunar soil samples to Earth. Luna 15, as well as Cosmos 300 and 305, were probably all part of a string of sample returner failures which began months before the Apollo 11 mission.

(3) Lunokhods landed near the local noon longitude of the Moon. This factor controlled when a Lunokhod was launched. There were only a few days available each year when a launch could be made to a specific landing area.

(4) Lunar orbiter launches showed little dependence on declination, but were launched close to a preferred age of 8.1 days. (This is in close agreement with the second generation Lunas 4–14 which were all launched near an age of 8.9 days.)

(5) Zond could only fly when the Moon's orbit and the Zond transfer orbit were close to coplanar. This effect, as well as lighting and declination considerations, combined to severely limit the number of launch opportunities available each year. There were no Zond flights between January and August of 1969 for the simple reason that there were no available launch opportunities.

It is clear that Soviet lunar launches were tightly constrained by the geometry of the Sun-Earth-Moon system. It appears that it was these constraints, more than any other single factor, that controlled the launch schedule.

Having looked in some detail at the separate elements of the Soviet lunar program it is difficult to end this project without first speculating, at least briefly, on the goals of the overall program.

OBSERVATIONS

The goal of landing men on the Moon and returning them safely to the Earth was met by Apollo. It is important to understand that Apollo was a system to carry men to the Moon and not necessarily a system developed to answer specific scientific questions about the Moon. Apollo was human exploration at its finest, and by the end of the program it also had yielded a rich harvest of scientific results.

In the early 1960s, Soviet cosmonauts often stated that they would be the first on the Moon. Such statements, coupled with an obviously aggressive Soviet lunar flight program, left little doubt that a race to the Moon was on. After the success of Apollo 11 the story changed, with the Soviets claiming they had planned all along to only use robot ships.

The Soviet piloted space program, at least in the early years, showed evidence of fundamental differences in design philosophy from the Americans. Man was integrated into the spacecraft in the American program and his presence was vital. Cosmonauts, on the other hand, were often riding in a ship which could have carried out much of the flight program without them. An example of this is rendezvous and docking which was not done with cosmonauts on board until after two successful remotely controlled missions involving automated Soyuz-type spacecraft (Cosmos 186/188 and 212/213).

Given this difference in design philosophy between the two countries, it is difficult to imagine a Soviet human landing program that had not been preceded by extensive lunar operations using robot ships. The four Zond circumlunar flights are certainly evidence of this reluctance to commit a crew until all flight details had been worked out in an automatic mode.

The sample returners, Lunokhods and orbiters all used common flight hardware and were obviously elements of an integrated program along with the Proton booster. We have seen evidence, however, that each of the different mission types had to operate within rather severe launch window constraints. These constraints were a direct result of the performance limitations of the flight systems.

If the sample returner capsule had been more complex, it could have performed more than a simple ballistic return flight and consequently could have landed in different areas of the Moon and flown at many different times of the month.

If the Zond had more propulsion and guidance capability it could have flown at times other than when the orbits were close to coplanar.

It seems that the Soviet designers developed a comprehensive system of probes for lunar exploration which were forced to operate within the lift capabilities of the Proton booster. The payload capacity of the Proton dictated the capabilities of the different mission payloads and the accompanying launch window constraints. If

it had worked as planned, the Soviets might have returned soil samples to Earth months before Apollo.

The following observations can be made about how the individual flights may have fit into the overall lunar exploration program.

(1) The Soviet Union developed an integrated program for lunar exploration consisting of both robot ships and a manned landing capability.

(2) The sample return, orbiter and Lunokhod probes used common flight hardware wherever possible in a unified program designed to explore the surface and obtain lunar soil samples before Apollo. Much of the technology of the robot exploration programs, such as the Luna descent stage, probably represented developmental versions of equipment which would be flown in the manned program. Experience in conducting complex operations at lunar distances as well as the command and tracking systems developed in support of these robot probes would have been directly applicable to manned lunar operations.

(3) Piloted lunar flights would not have been attempted before most elements of such a flight were successfully conducted in the automatic mode.

(4) The development of the Zond variant of the Soyuz spacecraft is evidence of a Soviet commitment to a program of human lunar exploration. While Zond could have carried a single cosmonaut on a circumlunar flight, its primary purpose was to test Earth reentry techniques for cosmonauts returning from the Moon.

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CHAPTER 3—SPACE APPLICATIONS

The Soviet Union uses satellites for a wide variety of space applications, including communications, meteorology, remote sensing of the Earth, navigation, search and rescue, and geodesy and mapping. They have also been active in research related to space manufacturing, and offer opportunities to fly foreign experiments on either automated spacecraft or on the space station Mir on a commercial basis.

COMMUNICATIONS

MOLNIYA 1

At the beginning of 1984 there were eight operational Molniya 1 satellites in planes spaced at 45° intervals, having ascending nodes at 115°W and 65°E on their North American and Asian loops. Replacements were launched at regular intervals through the end of 1986 but no launches were made during 1987. This prompted speculation that the role of the Molniya 1 had been assumed by geosynchronous satellites and that the series had been discontinued after more than 20 years of service. However, two new launches in March 1988, demonstrated that this was not the case!

Table 8 lists the Molniya 1 launches from 1984 through 1987.

TABLE 8.—MOLNIYA 1 SATELLITES: 1984–1987

Molniya Number and Designator		Launch Date	Apogee	Perigee	Inclination	Orbital Period	Days to get on Station
1–60	84–29A	3/16/84	39737	618	62.9	717.8	6
1–61	84–85A	8/10/84	39745	609	62.9	717.8	117
1–62	84–89A	8/24/84	39990	455	62.8	717.8	4
1–63	84–124A	12/14/84	39902	456	62.9	717.8	5
1–64	85–74A	8/22/85	39696	657	62.9	717.7	6
1–65	85–99A	10/23/85	39731	631	63.0	717.9	6
1–66	85–103A	10/28/85	39857	508	62.8	718.0	24
1–67	86–57A	7/30/86	39733	620	62.8	717.7	10
1–68	86–68A	9/5/86	39723	630	62.9	717.7	12
1–69	86–89A	11/15/86	39898	462	62.9	717.9	14
1–70	86–103A	12/26/86	39876	475	62.8	717.7	16

Notes:
1. Molniya 1–65 was launched from Tyuratam. All other launches were from Plesetsk.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
3. Orbits with 717.7 minute periods have stabilized ground tracks which repeat each day. Satellites are placed initially into orbits with higher or lower periods which allow them to drift to the desired location. The time elapsing between launch and the final maneuver to establish the stabilized ground track is given in the last column.
4. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
5. Table prepared for the Congressional Research Service by G.E. Perry.

Four satellites were replaced during 1984. Molniya 1–60 replaced Molniya 1–51 after 28 months. Although Molniya 1–61 was placed into the same orbital plane as Molniya 1–53, it did not stabilize its ground track at the first opportunity, five days later. Its initial 735

minute orbital period caused its ground track to drift westward until October 11, when the period was lowered to 713 minutes, changing the direction of daily drift from westward to eastward. Its ground track was eventually stabilized on December 4, nearly four months after its launch. Molniya 1-53, which, by then, was nearly three years old, had remained on station, and had probably still been operational, throughout this period. It has been suggested that this operation may have been a "deliberate test of on-orbit sparing or surge launching during a crisis situation."[1] In the meantime, Molniya 1-62, launched two weeks after Molniya 1-61, had replaced Molniya 1-54 after 27 months. At the end of the year, Molniya 1-63 replaced Molniya 1-55 after nearly 30 months.

Three more satellites were replaced in 1985. Molniya 1-64 replaced Molniya 1-61, which had been on station for only nine months. The short operational life of Molniya 1-61 coupled with the delay in stabilizing its ground track may signify that its performance had been somewhat lower than desired right from launch. Molniya 1-65, the first of two launches within five days of each other in October, was launched from Tyuratam—the only such Molniya 1 launch in the period under consideration. It replaced Molniya 1-58, which had also originated from Tyuratam 27 months earlier. Luni-solar perturbations had caused the perigee of Molniya 1-58 to drop dangerously low at the end of March 1985 and it had been necessary to perform corrections to its orbit to prevent it from decaying in the Earth's atmosphere. Molniya 1-66 replaced Molniya 1-56 which had been in orbit for more than two and one half years. Its initial daily drift of ground track was eastward and it was more than three weeks before it came on station and stabilized its ground track.

The four launches of 1986 were routine replacements, Molniyas 1-67 through 1-70 replacing Molniyas 1-59, 1-57, 1-60 and 1-54 after 33, 42, 33 and 29 months respectively. Molniya 1-70 also used the eastward daily drift launch profile which prolongs the time needed to come on-station.

The fact that all eight planes had been refurbished with new satellites, Molniyas 1-63 through 1-70, since the end of 1984 could explain the lack of requirement for any replacement launches in 1987.

Table 9 shows the replacement sequence of the Molniya 1 satellites in their respective planes.

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[1] Johnson, N. L. Soviet Space Programs 1980-1985. San Diego, CA., Univelt Inc., 1987. p. 63.

TABLE 9.—REPLACEMENT SEQUENCE OF MOLNIYA 1 SATELLITES: 1984–1987

	A		B		C		D		(A)
	57	58	51	54	55	56	53	59	
1			60						
9							61		
8				62					
4					63				
1							64		
9		65T							
8						66			
5									
1								67	
9	68								
8			69						
6				70					

Notes:
1. Groups A, B, C and D are separated by 90° in right ascension of the ascending node.
2. Molniya 1 numbers immediately below the double ruling at the head of the table indicate the operational status as of Dec. 31, 1983.
3. T indicates a Tyuratam launch. All other launches were from Plesetsk.
4. There were no Molniya 1 launches in 1987.
5. Table prepared for the Congressional Research Service by G.E. Perry.

MOLNIYA 3

At the beginning of 1984 there were five operational Molniya 3 satellites. Four were in planes spaced at 90° intervals, coinciding with the original four Molniya 1 planes, with ascending nodes at 115°W and 65°E. The fifth, Molniya 3-21, as reported in the previous chapter, was in a plane mid-way between two of the main planes.

Table 10 lists the Molniya 3 launches from 1985 through 1987.

TABLE 10.—MOLNIYA 3 SATELLITES: 1984–1987

Molniya Number and Designator		Launch Date	Apogee	Perigee	Inclination	Orbital Period	Days to get on Station
3–23	85–04A	1/16/85	39755	628	62.9	717.8	16
3–24	85–40A	5/29/85	39852	503	62.8	717.8	11
3–25	85–61A	7/17/85	39943	436	62.8	717.8	21*
3–26	85–91A	10/3/85	39738	609	62.9	717.6	27*
3–27	85–117A	12/24/85	39857	490	62.9	717.6	22*
3–28	86–31A	4/18/86	39739	613	62.8	717.7	11
3–29	86–49A	6/19/86	39726	630	62.9	717.8	13
3–30	86–79A	10/20/86	39724	625	62.9	717.7	10
3–31	87–08A	1/22/87	39897	457	62.9	717.8	28

Notes:
1. All Molniya 3 launches were from Plesetsk.
2. Satellites denoted by an asterisk established new planes and ground-tracks midway between the planes and ground-tracks of the original constellation.
3. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
4. Orbits with 717.7 minute periods have stabilized ground tracks which repeat each day. Satellites are placed initially into orbits with higher or lower periods which allow them to drift to the desired location. The time elapsing between launch and the final maneuver to establish the stabilized ground track is given in the last column.
5. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
6. Table prepared for the Congressional Research Service by G.E. Perry.

There were no Molniya 3 launches at all during 1984. However, in September, Molniya 3-21 relocated its ascending nodes, restabilizing its ground tracks in October with ascending nodes at 25°W and 155°E, mid-way between the usual locations.

The first two launches of 1985, Molniyas 3-23 and 3-24, replaced Molniyas 3-19 and 3-18 in the main planes after 29 and 39 months respectively. The final three launches of that year established new planes, mid-way between the main planes, completing, with Molniya 3-21, a constellation of four satellites in the same planes as four Molniya 1s but having ascending nodes in the mid-way locations at 25°W and 155°E. Nicholas Johnson suggested that the choice of the new locations could have been governed by employing them for maritime communications.[2]

Molniyas 3-28 and 3-29, in 1986, were routine replacements in the main planes for Molniyas 3-23 and 3-20 after 15 and 40 months respectively. Molniya 3-30 replaced Molniya 3-21, the first of the mid-plane satellites, which had been in orbit for more than three years, at the end of October 1986.

In the only launch of 1987, Molniya 3-31 replaced Molniya 3-21, the oldest of the operational satellites in the main planes, after nearly three and one half years. It stabilized its ground track in mid-February at the second opportunity.

Table 11 shows the replacement sequence of the Molniya 3 satellites in their respective planes and table 12 shows the right ascensions of the ascending nodes for all Molniya 1 and Molniya 3 constellations as of January 1, 1988.

TABLE 11.—REPLACEMENT SEQUENCE OF MOLNIYA 3 SATELLITES: 1984-1987

	A	B	C	D	(A)
	19	22	18	20	21
1	23				
9			24		
8				25	
5		26			
		27			
1	28				
9				29	
8					30
6					
1					
9		31			
8					
7					

Notes:
1. Groups A, B, C and D are separated by 90° in right ascension of the ascending node.
2. Molniya 3 numbers immediately below the double line at the top of the table indicate the operational status as of Dec. 31, 1983.
3. There were no Molniya 3 launches in 1984.
5. Table prepared for the Congressional Research Service by G.E. Perry.

[2] Johnson, op. cit., p. 63.

TABLE 12.—RIGHT ASCENSIONS OF ASCENDING NODES OF OPERATIONAL MOLNIYA SATELLITES AS OF JAN 10, 1988

Plane	Molniya	R.A.	Molniya	R.A.	Molniya	R.A.
A	1-68	358.4	3-28	357.8		
	1-67	43.6			3-30	42.3
B	1-64	95.8	3-29	92.9		
	1-66	138.5			3-25	138.2
C	1-63	195.1	3-24	185.8		
	1-70	222.1			3-27	223.2
D	1-69	266.7	3-31	261.0		
	1-65	315.2			3-26	311.8

Notes:
1. Molniya satellites occupy eight planes nominally separated by 45° in right ascension of the ascending node, R.A. The four original planes, nominally separated by 90° in R.A. are labeled here as A, B, C and D.
2. R.A. is given in degrees.
3. Table prepared for the Congressional Research Service by G.E. Perry.

GEOSYNCHRONOUS COMMUNICATIONS SATELLITES

Raduga

Two Raduga satellites were launched each year from 1984 through 1987. Some of the older Radugas were relocated during this period. It is helpful to consider this series of satellites in terms of the Statsionar locations which they occupy.

Statsionar 2 (35°E)

At the beginning of 1984 this location was occupied by Radugas 9 and 11. Raduga 9 failed and drifted off station in June 1985 and was replaced by Raduga 17, launched later that year. Raduga 11 and 17 were both on station at the end of 1987.

Statsionar 3 (85°E)

This location was occupied by Radugas 10 and 12 at the beginning of 1984. Raduga 14 joined them in February of that year. Raduga 12 failed in late summer 1984 although it had been in orbit for only a little more than one year. NORAD sensors "lost" Raduga 10 during 1985 and found it again in March 1986, still at 85°E.[3] It failed and drifted off station at the end of 1987. Meanwhile, Raduga 20 had been placed at this location in March 1987 and, since Raduga 14 had failed and drifted off station in September, was the only operational satellite in this position at the end of 1987.

Statsionar 8 (25°W)

This location was established during 1983 when Raduga 7 was moved from Statsionar 3. It was joined by Raduga 18 at the beginning of 1986. Raduga 7 failed at the beginning of 1987, after more than six years in orbit, leaving Raduga 18 as the only operational satellite at this location at the end of 1987.

[3] Johnson, N. L., *The Soviet Year in Space 1986.* Teledyne Brown Engineering, Colorado Springs, CO., 1987. p. 25.

Statsionar 9 (45°E)

Radugas 6 and 13 were both operational at this location at the beginning of 1984. Raduga 16 was launched into this location in 1985. Raduga 6, which started at Statsionar 2 in 1980 and moved here to establish the location at the end of 1982, finally failed and drifted off station in March 1986. Raduga 13 failed in July 1987, around the time that Raduga 16 was moved to establish the new Statsionar 10 location, leaving Raduga 19, launched in October 1986, as the only operational satellite at this location at the end of 1987.

Statsionar 10 (170° W)

As just mentioned, Raduga 16 was moved from Statsionar 9 between July and September to establish this location and remained operational there at the end of 1987.

Statsionar 15 (130°E)

This location was established with the launch of Raduga 15 in July 1984. This has been the sole occupant of the position and was still operational at the end of 1987.

Table 13 lists the Raduga launches from 1984 through 1987.

TABLE 13.—RADUGA COMMUNICATION SATELLITES: 1984–1987

Payload Name	Designator	Launch Date	Apogee	Perigee	Inclination	Orbital Period
Raduga 14	84–16A	2/15/84	35796	35772	1.3	1436.0
Raduga 15	84–63	6/22/84	35807	35752	1.3	1435.7
Raduga 16	85–70A	8/8/85	35831	35740	1.3	1436.0
Raduga 17	85–107A	11/15/85	35798	35791	1.4	1436.5
Raduga 18	86–07A	1/17/86	35782	35779	1.3	1435.8
Raduga 19	86–82A	10/25/86	35816	35760	1.2	1436.2
Raduga 20	87–28A	3/19/87	35804	35768	1.2	1436.0
Raduga 21	87–100A	12/10/87	35799	35779	1.3	1436.1

Notes:
1. All Raduga launches were from Tyuratam with the D–1e launch vehicle.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G.E. Perry.

Ekran

All Ekran direct broadcast satellites have been placed at the Statsionar-T location (99°E). The frequent launches to the single location coupled with the observation that more than two satellites remain close to 99°E over long periods suggest that either several Ekran satellites, each serving different areas of the Soviet Union, are operational simultaneously, or the operational lifetime is restricted by electrical/electronic considerations rather than supplies of attitude and station-keeping propellants.

Two Ekran satellites were launched in 1984. Ekran 12 failed at the end of the year and drifted off station but Ekran 13 stayed operational until August 1986. NORAD data showed five operational Ekrans (7, 10, 11, 12 and 13) on station at the end of 1984. However, it has been noted that Ekran 12 had already failed at that time and there was always some doubt as to the identification of

Ekran 7.[4] Moreover, Ekran 7 soon drifted away from 95°E in 1985. The status of Ekran 10 was also problematical in that current NORAD data was not available and Ekran 10 was off station and drifting when it was reacquired. Johnson recently postulated that three operational satellites at 99°E is the usual complement.[5] This is consistent with the announced objectives of serving portions of Siberia, the Extreme North and the Far East.

Ekran 14, launched in 1985, joined Ekrans 11 and 13 as the third satellite operational at the end of that year. Ekran 13 appeared to fail in August 1986. However, by then, it had been replaced by Ekran 16.

Ekran 11, which had been operational since September 1983, finally failed around the time that Ekran 16 was launched in March 1987. Ekran 14 failed in November 1987 and was replaced by Ekran 17. At the end of 1987 Ekrans 15, 16 and 17 formed the operational trio of satellites.

Table 14 lists the Ekran launches from 1984 through 1987.

TABLE 14.—EKRAN DIRECT BROADCAST SATELLITES: 1984–1987

Payload Name	Designator	Launch Date	Apogee	Perigee	Inclination	Orbital Period
Ekran 12	84-28A	3/16/84	35835	35736	0.1	1436.0
Ekran 13	84-90A	8/24/84	35816	35757	0.5	1436.1
Ekran 14	85-24A	3/22/85	35789	35777	0.4	1435.9
Ekran 15	86-38A	5/24/86	35810	35773	0.4	1436.4
Ekran 16	87-73A	9/3/87	35794	35769	0.4	1435.7
Ekran 17	87-109A	12/27/87	35851	35720	1.6	1435.9

Notes:
1. All Ekran launches were from Tyuratam with the D-1e launch vehicle.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

Gorizont

These satellites appear to have great longevity compared with some other families of Soviet satellites. As with the Raduga satellites, it is helpful to consider this series of satellites in terms of the Statsionar locations which they occupy.

Statsionar 4 (14° W)

Gorizont 4, launched in 1980, and Gorizont 7, launched in 1983 occupied the location at the beginning of 1984 and were joined by Gorizont 12 in 1984. All three were still operational to some extent at the end of 1987.

Statsionar 5 (53° E)

This location was occupied by Gorizonts 3 and 5 at the beginning of 1984. They were joined by Gorizont 9 in April 1984 and, four months later, Gorizont 3 was moved to establish the new Statsionar

[4] Johnson, N. L. *The Soviet Year in Space 1981.* Teledyne Brown Engineering, Colorado Springs, CO., 1982. p. 15.
[5] Johnson, N. L. *The Soviet Year in Space 1987.* Teledyne Brown Engineering, Colorado Springs, CO., 1988. p. 42.

12 location. Gorizont 9 failed and drifted off station in February 1987. Gorizont 11 was moved to this position from Statsionar 7 during February/March. It is possible that this maneuver was the result of the failure to place a new Gorizont at this location due to the malfunction of the fourth stage of the D–1e, Proton, launch vehicle on January 30. (The payload was given the Cosmos 1817 designation and there is some evidence that it could have been a Gorizont or Raduga satellite.) [6] After eight months of being "lost" by NORAD, Gorizont 5 was "found" at this location in March 1987. No orbital element sets are available between July 26, 1986, and March 18, 1987.[7] (Johnson believes [8] that there is a strong possibility that Gorizont 5 was moved to take over for Cosmos 1700, a data relay satellite used in conjunction with the Mir space station (see Part 1 of this study). There was no crew onboard Mir from July 1986 to early February 1987, however, and the Kettering Group did not monitor any transmissions from Romanenko and Laveikin suggesting their use of a communications relay satellite in February or March. Gorizont 5 was moved to establish the new Statsionar 14 location in April. Gorizont 11 was the operational satellite at this location at the end of 1987.

Statsionar 6 (90°E)

Gorizonts 6 and 8 occupied this location at the beginning of 1984. Gorizont 6 was moved to establish the new Statsionar 7 location during April 1984. Gorizont 13 was placed in this position at the end of 1986 and, shortly afterwards, Gorizont 8 was moved to Statsionar 7. Gorizont 13 was the only operational satellite at this location at the end of 1987.

Statsionar 7 (140°E)

This location was established by Gorizont 6 in May 1984 after it had been replaced at Statsionar 6 by Gorizont 8. Gorizont 11 was launched to join it in February 1985 but moved to Statsionar 5 in the spring of 1987 following the Cosmos 1817 failure. At that time, Gorizont 8 was moved here from Statsionar 6. Gorizont 14, launched in June 1987, Gorizont 6 and Gorizont 8 were all at this location at the end of 1987.

Statsionar 12 (40°E)

As stated above, this location was established by moving Gorizont 3 from Statsionar 5 in August 1984. No other Gorizont satellite has occupied this location and Gorizont 3 was still on station at the end of 1987 after eight years in orbit.

Statsionar 13 (80°E)

This location was first used by experimental relay satellites Cosmos 1336 and Cosmos 1540. Gorizont 10 was the first and only Gorizont satellite to be placed here in 1984 and was still in position at the end of 1987.

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[6] Johnson, N. L. *The Soviet Year in Space 1987.* Teledyne Brown Engineering, Colorado Springs, CO., 1988. p. 39, 41.
[7] op. cit., ref. 124, p. 140.
[8] op. cit., p. 43.

Statsionar 14 (95°E)

If the NORAD data are reliable, then Gorizont 5 established this location in April 1987, after being "discovered" in its original Statsionar 5 location, and was still there at the end of the year.

Table 15 lists the Gorizont launches from 1984 through 1987.

TABLE 15.—GORIZONT COMMUNICATION SATELLITES: 1984–1987

Payload Name	Designator	Launch Date	Apogee	Perigee	Inclination	Orbital Period
Gorizont 9	84–41A	4/22/84	35827	35743	1.5	1436.0
Gorizont 10	8478A	8/1/84	35844	35727	1.4	1436.0
Gorizont 11	85–07A	1/18/85	35917	35751	1.5	1436.0
Gorizont 12	86–44A	6/10/86	35806	35760	1.4	1435.9
Gorizont 13	86–90A	11/18/86	35796	35769	1.4	1435.9
Gorizont 14	87–40A	5/11/87	35792	35781	0.9	1436.0

Notes:
1. All Gorizont launches were from Tyuratam with the D–1e launch vehicle.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

Details of the Gorizont satellites were revealed in promotional literature published by V/O "Licensintorg".

Multichannel transponder hardware is mounted on board the satellite and radio reception and transmission is conducted with an assembly of 11 onboard antennas—zonal, semi-global and global. The zonal, or spot-beam, antennas serve regions with heavy schedules and their orientation is fixed during the launch preparation phase. In addition to the relay antennas, Earth-pointing antennas are rigidly fixed to the satellite's exterior.

> The Gorizont satellite relay system includes six transponders operating within the range 6/4 GHz, one 14/11 GHz transponder and one 1.6/1.5 GHz transponder.
>
> The 6/4 GHz transponders are multipurpose. They might be used for the TV signals relay, for a wide-range channel and a narrow-range channel telephone link, for broadcasting and for the reproduction of newspaper images. The transponder no 2 being distinguished by its increased power output has been designed for the transmission of the TV signals to a simplified receiving stations network with the aid of onboard high-gain transmitting antennas.
>
> A cross-link has been provided between the 1.6/1.5 GHz range transponder and that of 6/4 GHz allowing to make use of it when getting into contact either with the vessel to vessel-based floating stations within the range of 1.6/1.5 GHz or with the 6/4 GHz range ground stations.[9]

Cosmos Satellites

In addition to being used as a generic term assigned to satellites like Cosmos 1817 which fail in some respect, the Cosmos designa-

[9] Four-page brochure, *Soviet Communication Satellite Gorisont*, V/O "Licensintorg", 121108, Moscow, Minskaya str., 11.

tion has been applied to geosynchronous satellites which were obviously not failures. In general, these have settled down in recognized Statsionar locations and it is convenient to consider them from that aspect.

Statsionar 1/13 (80°E)

The Statsionar 1 location was originally given as 75°–85°E and then as 80°E. This location was later designated Statsionar 13.

Cosmos 1540 was placed in this position in March 1984 and had a similarly worded launch announcement to that for Cosmos 1366, placed there two years earlier. It was said to carry, in addition to scientific equipment, "experimental equipment for relaying telegraph and telephone communications in the centimetric band." It was still at this location at the end of 1987. Cosmos 1366 failed after five and one half years and drifted off station in October 1987. Cosmos 1546, for which no mission had been announced, moved here from Statsionar 8 during the first quarter of 1986 and failed at the beginning of 1987. When Cosmos 1888 was launched to this location in October 1987, the word "experimental" was dropped from the launch announcement.

Statsionar 8 (25°W)

Cosmos 1546 was launched just 27 days after Cosmos 1540 but no mission was announced for it. It drifted very slowly westward until taking up station at this location. Cosmos 1629, launched in February 1985, took six months to drift to this location before being stabilized here. Once again, no mission was announced. As noted in the previous paragraph, Cosmos 1546 was moved from this location to Statsionar 13 in 1986.

Cosmos 1894 was launched 27 days after Cosmos 1888. No mission was announced and it did not stabilize at this location until mid-January 1988 due to the slow westward drift. Nicholas Johnson drew attention to "the exact interval and pattern" between the Cosmos 1540/1546 and Cosmos 1888/1894 mission profiles without offering any explanation.[10]

Statsionar 14 (95°E)

This is one of the three locations announced for the Soviet Eastern Satellite Data Relay Network (ESDRN). Cosmos 1700 was stationed here in October 1985. Its launch announcement had similar wording to those for Cosmos 1366 and Cosmos 1540. It functioned as a communications link and data relay satellite for the cosmonauts on the Mir space station, when it was launched in 1986. From time to time it was also referred to as "Luch" (Beam). As described in vol. 1 of this review, it failed and began to drift off station in September 1986, after the cosmonauts had returned to Earth, and was not available to the new crew which was launched in 1987.

Cosmos 1897, launched at the end of November 1987, was the second in the series and the Kettering Group have monitored VHF down-link transmissions in which the cosmonauts were presumably

[10] Johnson, op. cit., p. 43.

lining-up a communications link to the Flight Control Center, through this satellite.

Statsionar 4 (14° W)

Cosmos 1738 was placed at this location in 1986. The launch announcement again had similar wording to that for Cosmos 1366 and Cosmos 1540.

A data relay system called Potok has been announced for a location at 13.5°W but its frequencies, in the 6/4 GHz bands, are not strictly centimetric in wavelength. (Other announced Potok locations are 168°E and 80°E.)

Table 16 lists the geosynchronous Cosmos satellite launches from 1984 through 1987.

TABLE 16.—GEOSYNCHRONOUS COSMOS SATELLITES: 1984–1987

Payload Name	Designator	Launch Date	Apogee	Perigee	Inclination	Orbital Period
Cosmos 1540	84–22A	3/2/84	35810	35755	1.4	1435.9
Cosmos 1546	84–31A	3/29/84	35801	35777	1.1	1436.2
Cosmos 1629	85–16A	2/21/85	35803	35775	1.4	1436.2
Cosmos 1700	85–102A	10/25/85	35814	35755	1.4	1436.0
Cosmos 1738	86–27A	4/4/86	35825	35745	1.4	1436.0
Cosmos 1817	87–10C	1/30/87	254	212	51.6	89.1
Cosmos 1888	87–84A	10/1/87	35805	35765	1.4	1435.9
Cosmos 1894	87–91A	10/28/87	35958	35833	1.4	1441.6
Cosmos 1897	87–96A	11/26/87	35820	35718	1.4	1435.1

Notes:
1. All geosynchronous Cosmos satellite launches were from Tyuratam with the D–1e launch vehicle.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Cosmos 1700 and Cosmos 1897 are data-relay satellites.
5. The D–1e fourth stage failed. Cosmos 1817 decayed on Mar. 18, 1987 after 47 days.
6. Table prepared for the Congressional Research Service by G. E. Perry.

THE INTERSPUTNIK SYSTEM

A session of the council of Intersputnik was held in Karl-Marx-Stadt, German Democratic Republic (East Germany), in September 1984. It was attended by delegations from all of the 14 member countries as well as observers from Algeria, India, Iraq, Syria, France and Yugoslavia. The People's Democratic Republic of Korea (North Korea) was granted membership in Intersputnik at this meeting. Use of a satellite in the area of the Indian Ocean (presumably at the new Statsionar 13 location at 80°E) to make it possible for a number of new countries to join the system was discussed and participants considered questions of establishing ground radio stations in Angola, the Yemen, Libya and Nicaragua, and the construction of a second ground radio station in Vietnam.[11]

In October 1984, Radio Moscow broadcast, in English, the text of a statement by Kurilov, the Director-General of Intersputnik, in which he disclosed that negotiations were under way with Asahi (Japan) for joint use of an Intersputnik satellite in 1985. Permanent membership in the organization was not obligatory for the use of the facilities of the system. In reply to a question, he denied that

[11] *TASS*, 1830 GMT, Sept. 24, 1984.

there were any limits to the transmission of information through Intersputnik channels and went on to claim that, compared with Intelsat, in which he claimed American companies held the controlling shares, financial and technological problems were "tackled more democratically" and that the procedure for obtaining a channel was much simpler. "The cost of transmissions is more reasonable too and the quality of transmitting information, according to experts, is no worse. Finally, unlike Intelsat, we do not forbid our members to join other organizations of the same type." He stated that it was not the purpose of Intersputnik to compete with Intelsat and that it had broken the monopoly of space communications in the world. As an example he cited the fact that the private American CNN telecast the Druzhba '84 international games.[12]

A report from Prague, Czechoslovakia, claimed that "some 60 percent of all TV transmissions in 1983 among the socialist countries were relayed by Intersputnik channels" and that the satellites "played a major role in news exchange by ten members of the Intervision network." [13]

A contract was signed in Moscow on December 8, 1984, for the Soviet Union to provide Syria with equipment and spares for an Intersputnik ground station as well as expertise during the installation period.[14]

The 14th meeting of the council of Intersputnik was held in Bucharest, Romania, in September 1985. Development of "promising new sets of equipment for ground stations" was outlined.[15]

At the 15th session of the council, held in Budapest, Hungary, from 14th to 18th October, 1986, it was noted that ground stations in the Yemen and Nicaragua had become operational and that other ground stations were being modernized. Construction of new ground stations in Syria, Kampuchea, North Korea, Libya and Czechoslovakia was discussed.[16]

The document on Nicaragua's accession to the agreement establishing Intersputnik was handed to the government of the Soviet Union "for safe keeping" on September 21, 1987.[17]

The 16th session of the Intersputnik Council opened in Warsaw, Poland, on September 28, 1987. It was reported that Japan wanted to take advantage of satellite links with Europe and was very interested in Intersputnik. It was decided to build, in the near future, ground stations in Syria, Libya, Algeria, Vietnam and Kampuchea. Radio and relay communications satellites would be placed over the Atlantic, after 1990, considerably increasing present transmission capabilities and offering transmission of digital radio and TV programs and telephone links to remote parts of the world. It was stated that Intersputnik makes a profit and, as an example, it was revealed that Poland makes about one million dollars annually for communications services between Spain and South America.[18] A

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[12] Moscow World Service, 1510 GMT, Oct. 18, 1984.
[13] CTK, Prague, 1331 GMT, Nov. 10, 1984.
[14] SANA, 1250 GMT, Dec. 8, 1984.
[15] *Izvestiya*, Sept. 29, 1985.
[16] *TASS*, 1025 GMT, Oct. 19, 1986.
[17] *TASS*, 1605 GMT, Sept. 22, 1987.
[18] PAP, 2134 GMT, Oct. 2, 1987.

decision was also taken to assist Angola with the establishment of television stations throughout the country.[19]

INMARSAT

The dish antennas of the Soviet Union's first international maritime satellite communications station, near Odessa, on the Black Sea, went into operation in 1984. One was directed towards the Indian Ocean, and the other to the Atlantic. Operational tests were made using the Intelsat 5 and Marecs A satellites in which prolonged telephone conversations were held with ships of the Soviet Ministry of Merchant Marine, including the Kazakhstan, Khudozhnik Kustodiyev, Smolniy, and Aleksandr Pushkin. The Black Sea gas turbine vessel Kapitan Smirnov and the Baltic motor vessel Prismorsk, which at the time were in the Indian and Atlantic Oceans were also linked via the Odessa-space-ocean radio bridge.[20] The station was declared operational at the end of 1984.[21] [22]

Trials with the second Coast Earth Station (CES), at the port of Nakhodka in the Soviet Far East, began early in 1985 and the station was due to become commercially operational later that year. It was fitted with Soviet electronic equipment but the antennas were supplied by Japan's Nippon Electric Industry Company.[23]

The Odessa CES was used to link Soviet explorers at the Antarctic station of Molodezhnaya with the Soviet Union.[24]

The status of various aspects of maritime communications, as of December 1, 1987, was presented in Inmarsat's house journal, Ocean Voice.[25]

The Soviet Union, through its signatory Morsviazsputnik, is the seventh largest shareholder in Inmarsat with a 2.34 per cent shareholding. Only the United States, United Kingdom, Norway, Japan, France and Singapore of the 51 member countries have larger shareholdings. The Soviet Union's shareholding includes the initial investment of the Byelorussian and Ukranian SSRs.

Although no Soviet organization is listed as a producer of ship terminals, there is an entry for the Soviet Union in the Ship Terminal Market table for the Inmarsat type-approved Volna-S model.[26] The 18 of these commissioning will bring the total to 173, with 2 more pending.

The CES at Odessa, serving the Atlantic and Indian Oceans, and the one at Nakhodka, serving the Indian and Pacific Oceans, are both operational. No other Soviet CES is listed as being in the planning stages.

In terms of the number of ship Earth stations (SES), the Soviet Union, with 4.08 percent of the total, comes sixth behind the United States, the United Kingdom, Panama, Japan and Liberia. The distribution within the different categories is given in table 17.

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[19] *The Namibian*, Windhoek, Oct. 23, 1987.
[20] Moscow for seamen, 0615 GMT, July 2, 1984.
[21] *TASS*, 1833 GMT, Dec. 27, 1984.
[22] Soviet television, 1530 GMT, Jan 30, 1985.
[23] *TASS*, 1240 GMT, Feb. 6, 1985.
[24] Moscow, 2004 GMT, Apr. 10, 1985.
[25] Ocean Voice. Inmarsat. London, Jan. 1988. p. 23–26.
[26] Ocean Voice, Apr. 1988, p. 30.

TABLE 17.—SOVIET SHIP EARTH STATION TERMINAL DISTRIBUTION

Bulk	59	Seismic	–
Container	29	Research	16
General	76	Passenger	15
Tanker	19	Yacht	–
LGC	2	Government	2
Rig	6	Land	6
Barge	–	Tug	2
Fishing	14	Miscellaneous	12
		Total	258

INTELSAT

Membership in Intelsat is open to any country belonging to the International Telecommunication Union (ITU) and only three, the Soviet Union, the German Democratic Republic and North Korea, have not availed themselves of that opportunity. The Soviet Union, as a non-owner user, sends observers to Intelsat meetings.

The Soviet Union showed interest in acquiring formal membership in Intelsat in 1985.[27] In March, Richard R. Colino, then Intelsat's director-general, and his deputy, Jose Luis Alegrett, visited the Soviet Union at the invitation, issued in January 1984, of Soviet minister of communications, Vasiliy A. Shamshin. The possibility of a memorandum of co-operation was raised. Addressing U.S. concern over possible transfer of technology, Alegrett said that this would be governed by existing Intelsat rules. Soviet membership would not automatically carry with it access to Intelsat's activities. The Soviet Union would not have a quota of Intelsat staff positions. As an Intelsat member the Soviet Union could invest in the organization and expect a return on its investment. It would also have one vote in the Assembly of Parties.[28]

Joseph N. Pelton, Intelsat director of strategic policy, said that a draft agreement had been sent to Moscow and that Soviet membership was pending.[29]

Later that year, a memorandum of understanding setting forth the rights and options of a non-owner user, as already specified in the Intelsat agreement, and defining a process and points of contact for increased use of the global network, was signed by the Soviet Ministry of Posts and Telecommunications and Intelsat.[30] Although this was expected to lead toward Soviet membership of the consortium, that has not happened.

AMATEUR RADIO

As noted in chapter 1, amateur radio satellites have been used to link stations in Antarctica with the Soviet Union. RS5 was used to relay a digitally encoded electrocardiogram to specialists in Moscow from the Soviet Druzhnaya base on the coast of the Weddell Sea. The cardiogram was stored in the satellite's memory and downloaded over Moscow 48 minutes later. It was telephoned to the

[27] Aviation Week and Space Technology, Mar. 25, 1985, p. 26.
[28] Ibid.
[29] Ibid.
[30] Aviation Week and Space Technology, Sept. 9, 1985, p. 15.

Institute of Biophysics of the Soviet Ministry of Health and immediately decoded. The diagnosis was returned to Antarctica using the same technique.[31]

No Soviet satellite dedicated to amateur radio support was launched from 1984–1987. However, two amateur radio transponders, RS10 and RS11, were incorporated in Cosmos 1861, a navigation satellite. The launch of Soviet amateur radio satellites RS9 and RS10 had been confidently predicted by the amateur radio community for more than two years and some details had been published, including provisional orbital parameters of 83°, 105 minutes, 1000 km, but it would appear that RS9 did not meet the necessary pre-launch checkout criteria and was by-passed. A newspaper report announcing the launch included the ambiguously worded statement, "two artificial satellites began work simultaneously . . . RS10 and RS11, launched together with Cosmos 1861." [32] Although this was taken in some quarters to imply that three separate satellites had been launched, Kettering Group reception of the radio transmissions from all three payloads indicated that all three were integrated into Cosmos 1861.[33] This was supported by the NORAD catalog which listed only two objects, 1987–54A and 54B, Cosmos 1861 and the final stage of the rocket which launched it.

Cosmos 1861 is a civilian navigation satellite in the Tsikada system, launched from Plesetsk on June 23. Transmissions on 150.00 MHz at 0945 GMT on June 24 were identified as emanating from Cosmos 1861 but, instead of transmitting its own parameter block, it was transmitting that for Cosmos 1727 with identity number 12. In the normal course of events, Cosmos 1861 could have been expected to replace Cosmos 1727 as number 12 in the operational constellation. However, on June 26, the standard navigation message transmission was switched on at 1950 GMT, and could immediately be identified on 29.350, 29.370 and 29.280 MHz in addition to breaking-in on the RS10 telemetry on 29.358 MHz. That was the first occasion on which the navigation message and amateur radio transponders had been observed to operate simultaneously.[34]

Presumably this unintentional cross-modulation posed problems and navigation message transmissions were discontinued, leaving the satellite to function as a dedicated amateur radio satellite through the end of 1987. It will be interesting to see if a new satellite is launched to replace Cosmos 1727 as number 12 when it eventually comes to the end of its serviceable life or whether Cosmos 1861 will be re-activated at the expense of its amateur radio role.

RS10 and RS11 were constructed at the Tsiolkovskiy Museum for the History of Cosmonautics at Kaluga, 180 km southwest of Moscow. Each uses the 15 meter band as an uplink only, the 10 meter band for downlinks only, and the 2 meter band for both uplinks and downlinks. Transponder power outputs are up to 5 watts and so the signals are very loud and easy to receive. Various

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[31] *TASS*, 1651 GMT, Feb. 16, 1984.

[32] *Sovetskaya Rossiya*, June 26, 1987.

[33] Perry, G. E. and D. G. Hawkins, Kettering Group Technical Memorandum GP/DH8701, reproduced in *SPACE*, E.S.R.U. University of Aston in Birmingham, no. 26, July 3, 1987; and *Oscar News*, AMSAT-UK, London, Sept. 1987. p. 24–25.

[34] Ibid.

combinations of uplink and downlink yield up to five distinct modes of operation.[35] Each mode employs five frequencies spaced at 10 kHz intervals above the basic frequencies quoted below. RS11 frequencies are 50 kHz above the corresponding RS10 frequencies. Uplink and downlink frequencies are 145.860 and 29.360 MHz, 21.160 and 29.360 MHz, and 21.160 and 145.860 MHz, for Modes A, K and T respectively. Modes KA and KT are combinations of modes K and A and modes K and T respectively. RS10 has beacons on frequencies of 29.357, 29.403, 145.857 and 145.903 MHz and RS11 beacons are 50 kHz higher than these. Robot uplink frequencies are 21.120 and 145.857 MHz for RS10 and 21.130 and 145.830 MHz for RS11. Both robot downlinks are on a frequency of 29.403 MHz.[36] (The "robot" device is described below.)

The telemetry represents various status indicators and measurements made on the transponders and is sent in a frame of 16 words. Each word consists of a four-character Morse code group. The first two characters are letters and the last two characters give a number in the range from 0 through 99. Each frame is preceded by an identifier, also in Morse code. A typical frame from an early pass is

RS10
GS81 GR00 RD11 RG45 SU45 SW00 SK00 SO00
US37 UR26 UD39 UG36 WU00 UW46 UK46 UO00

The first letter of each group determines in which half of the frame the particular word lies, whether or not the command station is accessing the satellite and, if so, in which waveband, according to the matrix below.

	Option	No command uplink	15 m command uplink	2 m command uplink
Words 1–8	First	I ..	S ...	D -..
	Second	N -.	R .-.	G --.
Words 9–16	First	A .-	U ..-	K -.-
	Second	M --	W .--	O ---

It will be noted that a dot is added in front of the character when the 15 m command uplink is employed and that a dash is added when the 2 m uplink is in use. There are two options for the meaning of the first character in each word. For example, if the first character of the first word is I then the telemetry data sampling period is 90 minutes, whereas if it is N then the sampling period is 10 minutes.

The sequence of the second letter in each group (S, R, D, G, U, W, K and O) is repeated in the second half of the frame. A logical explanation of the sequence can be derived by expressing these characters in Morse code dots and dashes, transposing the last of

[35] Limebear, R. W. L. RS10-11 Tech Data Manual, AMSAT-UK, London, 1988.
[36] Ibid.

these to the front and assigning values 0 to dots and 1 to dashes. This yields the ascending series of integers from 0 through 7 and thus the second character in each word determines its position in the particular half-frame.

The two-digit numeral specifies a particular parameter value which may be derived by substitution in a transfer function. For instance, in the example provided above, the twelfth group is UG36. The U shows that the word is in the second half-frame, that the command station is accessing the satellite on the 15 m uplink and that the first option should be considered. The G signifies the fourth word of the second half-frame, which has the options of the codestore memory being "open" or "closed"—in this case "open"—and provides the temperature of the 9 V power supply. Substitution in the formula

$$T = N - 10°C$$

reveals that the temperature of the power supply was 26°C.

For full details of the telemetry coding the reader is referred to papers in the amateur radio literature.[37]

Normal radio contacts between licensed amateurs world-wide can be established through the RS10 and RS11 transponders. In Mode A, a transmission to RS11 on a frequency of 145.930 MHz is rebroadcast by RS11 on 29.430 MHz and can be received by any shortwave listener within the satellite's footprint. The listener can then reply on, for example, 145.950 MHz and the original caller will receive that reply, rebroadcast from RS11 on 29.450 MHz. Theoretically it would be possible for two stations separated by as much as 7,400 km to communicate, whereas the normal range of a 2 meter transmission is limited to line-of-sight or some tens of kilometers only. Under certain ionospheric conditions even greater ranges have been reported due to anomalous propagation conditions.

The first radio contact through the new satellite was made by Master of Sports Valeriy Petrov in Alma-Ata. The report of this went on to say that some 800 individual and 250 collective radio stations in the Soviet Union are operating via artificial Earth satellites and that more than 3,500 foreign radio stations from 75 countries make use of Soviet RS satellites for the retransmissions of their signals.[38] Another report on the following day, June 26, 1987 stated that RS10 and RS11 would be switched on for work with shortwave enthusiasts world-wide at 0928 Moscow Time today (emphasis added).[39]

The "Robot" is a useful device with which a radio amateur can have a contact as opposed to communicating with a fellow amateur via the satellite. The Robot transmits a "call" and expects to be answered on its declared uplink frequency with its own callsign and the amateur radio operator's callsign. If the correct procedure is followed it then responds with a serial number. The Morse code character-pair "AR" must be sent without a break as di-dah-di-dah-dit.

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[37] Ibid.
[38] *TASS*, 1420 GMT, June 25, 1987.
[39] *Sovetskaya Rossiya*, June 26, 1987.

A typical example to illustrate the full procedure is given below. The satellite transmits the sequence

CQ CQ DE RS10 QSU 21120 KHZ AR

which may be interpreted as "General call, general call from RS11. Send your reply on 21.120 MHz." A typical reply might take the form

RS10 DE G3FOZ AR

which is "RS10 from G3FOZ, please acknowledge." If the operator's message is correctly received the satellite will reply

G3FOZ DE RS10 QSL NR 10 OP ROBOT TU QSO NR 10 73 SK

acknowledging the contact and allocating the contact number 10. All the callsigns worked are stored in memory and downloaded by ground command.

METEOROLOGY

All Meteor satellites launched from 1984 to 1987 were launched from Plesetsk by the F-2, or Cyclone, booster. Meteor 2-11, in 1984, was the second of the improved type with new microwave equipment and flew at the increased altitude and orbital period employed by Meteor 2-8 in 1982. It began transmitting on 137.3 MHz, but a decrease in signal strength and a consequent deterioration in image quality led to a change to its back-up transmitter on 137.85 MHz in April 1985. By the end of that year the synchronization had disappeared and transmissions were discontinued.

The other 1984 launch was given the Cosmos 1612 designation and was something of a mystery until the first Meteor 3 appeared in October 1985. The 1230 km apogee of the eccentric Cosmos 1612 orbit closely matched the 1227 km perigee of the new Meteor 3 and the implication that Cosmos 1612 was the first flight of a Meteor 3 spacecraft cannot be ignored. It would appear that the second stage of the F-2 failed to restart at apogee to produce the desired circular orbit with the 110 minute orbital period and the satellite decayed in the Earth's atmosphere on January 31, 1985, 65 days after it was launched.

The launch announcement of Meteor 2-12 referred to a capability to produce both visible and infra-red cloud cover imagery in either stored or direct transmission modes.[40] Automatic picture transmission (APT) was on 137.4 MHz and by October 1985 it was experiencing synchronization problems. It was switched off when the new Meteor 3 was launched at the end of the month.

Meteor 2-13, at the end of the year, initially transmitted its APT on 137.3 MHz, but at somewhat reduced power than was usual. On April 4, 1986, Marciano Righini, of Ravenna, Italy, noted that, during the pass around 1330 G.M.T., it showed "a severe malfunctioning of the onboard transmitter which worked at intervals only for a few seconds, then the carrier was switched off." [41] Four days

[40] *TASS*, Moscow, Feb. 7, 1985.
[41] Righini, M. Private communication, Apr. 4, 1986.

later, Kettering Group member Peter Wakelin, at Sunningdale, England, discovered its transmissions on 137.4 MHz. At the time of the malfunction, the orbital period was reduced from 104.120 minutes to 104.108 minutes by lowering the mean orbital height by less than one kilometer. It would appear that the maneuver and malfunction were related in some way although the reason for such a small maneuver is not immediately obvious. Prior to the maneuver the ground-track pattern repeated every 289 orbits over a period of a little less than 21 days. Following the maneuver this had changed to 234 orbits in a little less than 17 days. Whatever the reason, the transmissions were terminated following the launch of Meteor 2-14 at the end of May.

Kettering Group observations revealed that Meteor 2-14 developed a fault at some time during the first two weeks of June. It had been shown that the black bars of varying widths at the side of the image were an analog-binary read-out of the iris aperture. This edge-code takes values decreasing from 63 at full aperture when the solar elevation at the sub-satellite point is around 5°, the minimum illumination at which the APT normally operates, to 10 or less at minimum aperture when the Sun is overhead at the sub-satellite point.[42] Len Maxim, in Wellington, New Zealand, reported an unbroken decrease in values from 63 through 45 during a northbound pass on May 31. By June 17, Peter Wakelin, by then at R.A.F. Mount Pleasant, Falkland Islands, and Maxim reported sequences of values in cycles of seven, with discontinuities in edge-code value of 15 between pairs of cycles: thus 63 62 61 60 61 62 63 48 49 50 51 50 49 48 47 46 45 44 45 46 47 32 33 34 35 34 33 32. The imagery showed corresponding abrupt changes in intensity [43] coincident with these discontinuities and the fault persisted until the transmissions were eventually terminated in February 1988 following the launch of Meteor 2-17. Transmissions were switched from the initial frequency of 137.3 MHz to 137.85 MHz in late September 1986 dictating Meteor 3's reversion to its original frequency, as mentioned below.

Meteor 2-15 was launched at the beginning of 1987 and began transmitting APT on 137.4 MHz but, one week later, switched to its second transmitter on 137.85 MHz and was still operational on that frequency into 1988. Thus, throughout 1987, two satellites were operational on the shared frequency but, since there was an orbital plane separation of approximately 90°, little mutual interference was observed.

Meteor 2-16 has transmitted on 137.4 MHz from launch into 1988. Its launch on August 18, 1987, coincided with the reappearance of transmissions on 137.30 MHz which Wakelin identified as emanating from Meteor 2-3, launched at the end of 1977. It transpired that it was in practically the same orbital plane as Meteor 2-16 and the possibility that it was reactivated by a command sent to the new Meteor cannot be ruled out since, as viewed from Soviet command stations, both satellites had similar altitudes and azi-

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[42] Perry, G. E. Proceedings 1979 Australian Astronautics Convention, Perth, Western Australia, v. 1, 1981. p. 75-83.

[43] An example occurs near the top of Leslie Currington's image reproduced as figure 24 (from which the edge-code has been removed) in Johnson, N. L. *The Soviet Year in Space 1986.* Teledyne Brown Engineering, Colorado Springs, CO., 1987. p. 32.

muths at the time the transmissions reappeared.[44] An explanation for the readiness of Meteor 2-3 to accept such a command after almost ten years lies in the observation that, at the time, it was in a solar orbit.[45]

The only Meteor 3 launch to date came between the launches of the two Meteor 2s in 1985. The launch announcement referred to optico-mechanical television equipment and radiometers and its APT imagery was indistinguishable from that of the Meteor 2s. Its initial near-circular orbit at a mean height of 1244 km came close to providing the complete equatorial coverage promised in the 1981 National Paper to the United Nations and achieved almost perfect ground-track stability. During its operational life it carried out several maneuvers characteristic of the employment of low-thrust ion engines. For three days in mid-November, soon after launch, there was no APT imagery. This coincided with the start of a period of reduction in mean orbital height amounting to some 20 km by the end of the month. Another reduction of some 20 km in mean orbital height in late December was also accompanied by a period during which APT was not received. At the end of this period an 11-day ground-track repetition every 144 orbits had been established at the cost of losing complete coverage of the equatorial zone. A further "silent" period from June 29 through July 2, 1986, coincided with another reduction in mean orbital height, this time by only 4 km.

Meteor 3 began sending APT imagery on 137.4 MHz but switched to its second transmitter on 137.85 MHz at the end of February 1986. On April 10 it was observed sending an all-black image during a nighttime pass over North America.[46] By the Fall of 1986 it was experiencing synchronization trouble and it reverted to its original frequency. Edward Zigoy reported that it entered a regime of reduced operation at the beginning of December and that the APT signal continued to degrade until transmissions finally ceased in late February 1987.[47]

At the end of 1987, Meteors 2-14, 2-15 and 2-16 were operational. Meteor 2-14 was replaced by Meteor 2-17 at the end of January 1988. At that time the orbital plane spacings were close to 60° and each satellite employed a different transmission frequency. If the Soviet claim of an active life of three to four years for each satellite [48] can be substantiated, then this constellation might survive until an operational constellation of Meteor 3s can be established.

At least one Meteor launch is planned for 1990. An agreement on Soviet-U.S. space cooperation, signed at the Moscow summit meeting in 1987, calls for placing an American-built ozone mapping instrument, similar to Nimbus 7's Total Ozone Mapping Spectrometer, on the Soviet satellite.[49]

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[44] Currington, L. Remote Imaging Group Newsletter. Leighton Buzzard, England, Sept. 1987. p. 16

[45] When the angle between the solar vector, from the Earth's center to the Sun, and the orbital plane of a satellite (the beta-angle) approaches 90°, the satellite will not enter the Earth's shadow for a period of several days. It is then said to be in a solar orbit. This sometimes has the effect of recharging spent electrical batteries sufficiently for transmissions to be resumed, with or without command from Earth.

[46] Zehr, G. Private communication, Apr. 10, 1986.

[47] Zigoy, E. A. *Journal of the British Interplanetary Society, 1988.* p. 285-286

[48] Chernyshov, M. *Sovetskaya Kirgiziya.* Frunze, Sept. 17, 1986. p. 4.

[49] *Nature,* London, June 9, 1988. p. 490.

The first instance of a regional center for receiving and processing meteorological information from Meteor satellites for weather forecasting appeared in the announcement of the creation of such a center in Tashkent.[50] Photographs, received four times a day, cover an area from the Indian Ocean to the Arctic Circle, and from Central Europe to East Siberia. The zone served by the Tashkent center includes the massive mountain ranges of Asia where there are no weather stations and copies of the maps produced at the center are distributed to 15 countries, including Afghanistan, India, Iran, Iraq, Pakistan and Sri Lanka.[51]

Table 18 lists the meteorological satellites from 1984 through 1987.

TABLE 18.—METEOROLOGICAL SATELLITES: 1984–1987

	Satellite name and designator	Launch Date	Apogee	Perigee	Inclination	Orbital Period
Meteor-2						
Meteor 2–11	84–72A	7/5/84	960	943	82.5	104.1
Meteor 2–12	85–13A	2/6/85	961	939	82.5	104.1
Meteor 2–13	85–119A	12/26/85	962	939	82.5	104.1
Meteor 2–14	86–39A	5/27/86	960	941	82.5	104.1
Meteor 2–15	87–01A	1/5/87	961	942	82.5	104.1
Meteor 2–16	87–68A	8/18/87	960	944	82.6	104.1
Meteor-3						
Cosmos 1612	84–120A	11/27/84	1230	135	82.6	98.4
Meteor 3–01	85–100A	10/24/85	1251	1227	82.6	110.3

Notes:
1. All satellites launched by F-2 from Plesetsk.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Cosmos 1612, which decayed 1/31/85 after 65 days in orbit, is believed to have been an intended Molniya 3 which failed to circularize its orbit when the second stage did not re-start at apogee.
5. Table prepared for the Congressional Research Service by G. E. Perry.

REMOTE SENSING

Plans for the establishment of a system named Resurs were disclosed at the beginning of 1984. Resurs would provide regular remotely-sensed data every five to seven days for "monitoring all sorts of natural phenomena important to man—atmospheric an ocean processes, possible changes in the Earth's geological structure and the like." [52] It was noted that the currently operating experimental system, involving several satellites of the Cosmos and Meteor-Priroda series, was actually the first stage in building-up the Resurs system.[53]

A paper by Arnold Selivanov, of Glavkosmos, made available at a meeting for representatives of industry and the media,[54] sponsored by the British insurance brokers, Jardines, provided further details on the type of imagery that would be made available on a commer-

[50] Artemenko, V. and Yu. Chernogayev. *Pravda*, Moscow, Jan 7, 1987. p. 6.
[51] Ibid.
[52] Moscow for North America, 2300 GMT, Jan. 27, 1984.
[53] *Ibid.*
[54] Hadlington, S. London. Nature, Nov. 12, 1987. p. 98.

cial basis as a result of policy changes in the Soviet Union.[55] Three systems, one long-term and two short-term, make up a big State satellite system, named Resurs, according to the paper.

Resurs-F is a photographic system using satellites which take photographs and return the film to Earth, providing high quality images but having a lengthy wait to fill orders. In the other two systems, Resurs-O and Okean-O, images are transmitted to the ground by radio-link permitting rapid observation of short-term processes and phenomena with a fast delivery of information to consumers.

Resurs-O spacecraft are of the Landsat-type with Cosmos 1689 being the most recent. Okean-O spacecraft are of the Cosmos 1500-type and carry side-looking radar among their sensor-systems.[56] The Resurs-F spacecraft were not identified at that time, but it was not unreasonable to presume that they were Cosmos satellites flying in 82.3° inclination orbits with periods of less than 90 minutes which flew two-week missions. As reported below, this conjecture was justified by later revelations.

There are three ground stations within the Soviet Union which receive information from remote sensing satellites: near Moscow, in Novosibirsk and in Khabarovsk. These provide real-time observation of the Soviet Union and several neighboring countries and onboard memory permits observations in the global mode. More than 100,000 examples of imagery are disseminated to consumers annually.[57]

The opening of a new computing center, in Tajikistan, to process images of Earth brought from space was announced in 1985. Previous observations were said to have helped discover oil and gas deposits in the area and images of the Pamir mountains in that republic had made it possible to give advanced warning of movements of glaciers, avalanches and mud flows.[58] A similar center was established at Krasnoyarsk in southern Siberia in the following year.[59]

SOYUZKARTA

The Department of Geodesy and Cartography at the Soviet Council of Ministers, which in 1987 was granted the right to engage in direct foreign economic relations, established the Soyuzkarta (Union Map) foreign trade association for the purpose of marketing imagery from the Resurs program.

Department chief Viktor Yatsenko said that they had a rich experience in photographing the Earth from space and that the photographs provided by Salyut space stations were used by many industries. They were taken from a height of about 300 km and had the smallest resolution of 6 meters. Space photographs, he said, help find land suitable for farming and irrigation, and natural pastures and water resources, and are used to prospect for coal, oil and gold.

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[55] Selivanov, A. S. Research of the Earth from space in interest of economy and the preservation of the environment. Unpublished.
[56] *Ibid.*
[57] *Ibid.*
[58] Moscow. 0800 GMT, Dec. 9, 1985.
[59] Moscow. 0800 GMT, Nov. 30, 1986.

He added that quite a few countries had requested space photographs of their territory, notably Australia, Kuwait, Angola, North Korea, Vietnam and the German Democratic Republic.

He also revealed that a training center in Dushanbe, Tajikistan, would teach foreign specialists to interpret space photographs.[60]

Vyacheslav Piskulin, director general of Soyuzkarta, revealed that they had concluded a five-year agreement with the Australian Technical and Field Survey for space surveys of Australia and surrounding areas by satellite. The contract can be extended by mutual agreement. Under the contract, information gained, which will show features as small as five to ten meters across, will be kept confidential to the countries concerned.[61]

METEOR-PRIRODA

Meteor 31, the last satellite in the experimental program, was launched in 1981. Its predecessor, Meteor 30, launched in 1980, still continues to produce good APT imagery at 4 lines per second to this day, although the edge-code telemetry and gray-scale step-wedge have long since disappeared. The transmission frequency has drifted significantly from its initial 137.150 MHz and had fallen to 136.975 MHz by June 11, 1988, when transmissions were terminated on the eighth anniversary of its launch. During 1985 the transmission frequency decreased from 137.075 to 137.055 MHz. In the following year it fell to 137.020 MHz and by the end of 1987 it was down to 136.990 MHz.

Details of the performance of the Meteor-Priroda (Nature) satellites were provided in a booklet made available at the 38th Congress of the International Astronautical Federation (I.A.F.) at Brighton, England, in 1987.[62] The Fragment multispectral system produced line-scan images with 80 meter resolution with a swath-width of 85 kilometers at the Earth's surface. The four-channel MSU-M and two-channel MSU-S provide low and medium resolution respectively. High resolution imagery is provided by the conical-scan MSU-SK and a three-channel pushbroom MSU-E employing linear arrays of charge-coupled devices (CCD) situated in the focal plane of the lens. The MSU-SK provides 250 meter resolution with a 600 kilometer wide field of view. MSU-E has a 30 meter resolution—the effective width of one CCD element of the linear array.

Information from a Meteor-Priroda satellite was used by specialists to assist in the choice of "rest-zones in the Moscow region." [63]

LANDSAT-TYPE SATELLITES

The next phase of the Soviet sun-synchronous remote sensing program, recently acknowledged as Resurs-O, initiated by Cosmos 1484, was continued by Cosmos 1689, which was launched from Tyuratam on October 3, 1985, by an A-1, into a near-circular, 600 km orbit with a 97.0 minute orbital period and a 98.0° inclination.

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[60] Novosti Press Agency, London. USSR Space Bulletin, SB15, July 22, 1987. p. 3-4.
[61] Novosti Press Agency, London. USSR Space Bulletin, SB23, Oct. 30, 1987. p. 3-4.
[62] Astachkin, A., A. Pechkin and N. Yusatova. Space Technology Serves Economic Needs. Novosti Press Agency Publishing House, Moscow, 1987. (pages unnumbered)
[63] *Sotsialisticheskaya Industriya*, Nov. 11, 1984.

Selivanov revealed that these satellites are "still largely experimental in nature" in a newspaper interview.[64] He said that Cosmos 1689, which was operational in 1985–86, had a television apparatus which provided images with resolutions of 45, 170 and 200 meters with swath-widths at the Earth's surface of 45, 600 and 1,400 kilometers respectively. The onboard apparatus was said to be especially suitable for observation of "the hydrological situation, vegetation, forest fires and the spread of pollution." [65] Cosmos 1939, similar to Cosmos 1689, was launched in 1988.

COSMOS 1870

A new development in the Soviet remote sensing program appeared with the launch from Tyuratam on July 25, 1987, of Cosmos 1870. Use of the D–1, or Proton, launch vehicle was acknowledged in the launch announcement, which gave the initial orbital parameters as "88.7 minute, 282–168 km", but omitted the inclination.[66] The flight program envisaged "testing the design of the onboard systems and the satellite's scientific instruments, and conducting scientific-technical research and experiments in the interests of various branches of science and the national economy, including hydrology, cartography, geology, agriculture and the study of the environment." [67]

A later announcement reported the orbital parameters, following a trajectory correction, as "89.5 minute, 271–254 km, 71.9°." [68] The 71.9° inclination was the highest attained with the D–1. The announcement went on to say:

> 1The scientific apparatus of the satellite includes a radar station intended for remote sounding of the Earth's surface and ocean, regardless of weather conditions or time of day. . . .
>
> In accordance with the program, the first radar soundings took place today [August 2] of separate areas of dry land and the ocean waters. The information being received by means of Cosmos 1870 will be transmitted to institutes of the Soviet Union Academy of Sciences and to other interested organizations for study and use in various branches of science and the Soviet economy.[69]

Sven Grahn, in Sweden, discovered FM telemetry, 250 kHz wide, on a center-frequency of 180.0 MHz on July 31 but, despite repeated attempts, the Kettering Group has not succeeded in detecting any radar imagery.

Atmospheric drag at perigee, which is maintained close to 240 km, is considerable, notwithstanding the great mass of the spacecraft which may be of the order of 1020 tonnes. Consequently, a routine of periodic adjustment of apogee was established, raising the apogee to around 265 km once it had fallen to around 250 km, every 1112 days, at the same time maintaining perigee deep in the

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[64] *Leningradskaya Pravda*, Leningrad, Dec. 31, 1987, p. 3.
[65] *Ibid.*
[66] *TASS*, 1435 GMT, July 25, 1987.
[67] *Ibid.*
[68] *TASS*, 1426 GMT, Aug. 2, 1987.
[69] *Ibid.*

southern hemisphere. This regime has persisted through June 1988 and Western analysts are wondering how long it can continue before its maneuvering propellant becomes exhausted or will some type of re-supply mission, crewed or uncrewed, be mounted with a Soyuz or Progress-type spacecraft."

It is understood that, although products of the imagery from Cosmos 1870 is not currently offered for sale, the system will be referred to as Resurs-R.[70]

OCEANOGRAPHIC SATELLITES

Okean-O satellites, introduced with Cosmos 1500 in 1983 have the primary task of observing the ice situation in the Arctic and Antarctic under conditions of cloudy weather and polar night. An important feature of these satellites is the capability of transmitting information to simplified reception stations such as are found at polar stations or onboard ships. These satellites are currently operational. Side-looking radar provides one kilometer resolution with a swath-width of 450 kilometers.[71] The radar was designed by scientists at the Kharkov Institute of Radio Physics and Electronics of the Ukranian Academy of Sciences under the direction of Anatoliy Kalmykov.[72] The head of the department of remote sensing of the Academy's Marine Hydrophysical Institute, Yuri Terekhin, claimed that Cosmos 1500 supplied valuable information to 53 research stations in various parts of the Soviet Union.[73] The radar was said to be almost the same as that carried by Venera 15 and Venera 16 to map the cloud-covered surface of Venus.[74]

In addition the satellites carry scanning and non-scanning three-channel SHF radiometers, which are able to detect surface thermal radiation within a radius of 330 km from the sub-satellite point and which have become "indispensable for obtaining images of cold and warm currents, compiling temperature charts, and calculating the speed of winds, rough sea zones and areas of intense precipitation."[75]

Papers presented at the 35th Congress of the I.A.F. in Lausanne, Switzerland, described the instrumentation and modes of operation of Cosmos 1500.[76] The side-looking radar operates at a wavelength of 3.15 cm, providing 1.52 km resolution over a viewing field of 460 km. An improved multichannel low-resolution scanner provides imagery in the four spectral bands: 0.5–0.6; 0.6–0.7; 0.7–0.8; 0.8–1.1 microns. The viewing field from the height of 650 km is 1,930 km with a ground resolution of 1.5 km. The side-looking radar and the multispectral scanner can function simultaneously, having the same line scanning uniform at the Earth's surface. The satellite information system is capable of either performing direct transmission or preliminary recording by the memory and subsequent reproduction within the radio-range of the receiving centers. The memory can

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[70] Jardine Interplanetary Ltd. Private conversation.
[71] The booklet by Astachkin et al. cites 460 km for the swath-width.
[72] *TASS*, 0926 GMT, Aug. 9, 1985.
[73] *TASS*, 0800 GMT, Jan. 23, 1984.
[74] *TASS*, 2048 GMT, Nov. 11, 1984.
[75] Astachkin, A., et al. op. cit.
[76] Afans'ev, Yu.A., et al. The Experimental Oceanographic Satellite Cosmos 1500. 35th Congress of the International Astronautical Federation. Lausanne, Switzerland, Oct. 7–13, 1984.

store 6.5 minutes of data providing image-strips 2,750 km in length at the swath-widths quoted above. This permitted the production of maps of the Arctic and Antarctic ice-caps.[77]

Data are received and processed by the three main centers and at regional centers, shown on a sketch-map, at Leningrad, Petropavlovsk-Kamchatka, Yuzhno-Sakhalinsk, and four locations along the northern seaboard of the Soviet Union, and shipboard receiving stations. The 137.4 MHz transmission can provide any of the four-channels of the multispectral scanner; side-looking radar; or the combined frame of the fourth channel of the multispectral scanner and the side-looking radar. A transmission on the international 466 MHz frequency can provide all four channels of the multispectral scanner or the first three channels and the combined frame of the fourth channel and the side-looking radar.[78]

Kettering Group observations of the 137.4 MHz transmissions show a scan rate of 4 lines per second, as with the APT from the Meteor-Priroda series. An edge-code resembling a "piano keyboard" is present whenever the side-looking radar image is transmitted.[79]

In October 1984 Cosmos 1500 rendered practical help to navigators in the eastern sector of the Arctic where, in the area of the Long Strait and the port of Pevek, a caravan of ships was icebound. Radar images transmitted from the satellites enabled specialists quickly to assess the ice situation and send information to the administration of the Northern Sea Route and directly to the center of sea operations in Pevek.[80]

In 1985 the satellite transmissions helped rescue the research ship *Mikhail Somov* which was ice-bound in the Antarctic. Radar observations made it possible to locate cracks and passages through which the icebreaker Vladivostok sailed thousands of kilometers to reach the *Mikhail Somov.*[81] The tracing of river floods on the territory of the Soviet Union was described as a "new task" for Cosmos 1500 at the beginning of 1986.[82] Reconstructed pictures of the River Amur and its valley on August 20, 1985, accurately revealed flooded and dry areas, corresponding respectively to darker and brighter spots on the radar imagery.[83]

Cosmos 1602 and Cosmos 1766 had similar imagery on 137.4 MHz and the storage capability was observed with Cosmos 1602, Wakelin receiving a visible image of Japan at Sunningdale on November 29, 1984. The numerical edge-code gave a minute-count between 376 and 380 minutes after midnight Moscow Standard Time, some six and one quarter hours earlier, when Cosmos 1602 was southbound down the east coast of the Peoples Republic of China.

Cosmos 1766 was reported as having taken over regular control of the Arctic seaway in September 1986. Its radar was said to be capable of determining the difference in the thickness of ice, sec-

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[77] Burtzev, A. I. et al. Monitoring of the Arctic and Antarctic Ice Cover with Cosmos 1500 Satellite Radar Images. 35th Congress of the International Astronautical Federation. Lausanne, Switzerland, Oct. 7-13, 1984.

[78] *Ibid.*

[79] An example of this imagery is to be found in Johnson, N. L. *The Soviet Year in Space 1986,* figure 26. Teledyne Brown Engineering, Colorado Springs, CO., 1987. p. 35.

[80] Astachkin, A., et al. op. cit.

[81] *TASS,* 1558 GMT, Nov. 15, 1985.

[82] *TASS,* 1640 GMT, Jan. 21, 1986.

[83] Pichugin, A. P. et al. *Doklady Akademii Nauk S.S.S.R.* Moscow, Sept. 1985. p. 323-326.

tions of sea free from ice and the movement of ice fields. The data was aiding specialists in outlining optimum routes for vessels moving along the Arctic coast.[84] The side-looking radar onboard Cosmos 1766 was described as the first "industrial" model.[85]

Plans to expand the Okean-O system suffered a partial setback in 1987. Cosmos 1869 was launched into a plane 60° away from Cosmos 1766 so that it followed it some two orbits later. However, the side-looking radar antenna failed to deploy correctly.[86] Contrary to the belief that no attempt was made to activate the radar for fear of damaging other equipment, Leslie Currington at Welwyn Garden City, England, did receive imagery with the pianokey edge-code, characteristic of transmissions of radar imagery, on August 5, but the imagery was of very poor quality and he did not make a hard copy before erasing the tape. The replacement promised for early 1988 [87] had still not put in an appearance by June 1. Nevertheless, other equipment onboard Cosmos 1869 functioned normally and stored imagery was received in September 1987.[88]

Although Cosmos 1500 was launched in 1983 it is included in table 19, which lists all Okean-O satellites, for completeness.

TABLE 19.—COSMOS SATELLITES IN THE OKEAN-O PROGRAM

Cosmos number and designator		Launch Date	Apogee	Perigee	Inclination	Orbital period
1500	83-99A	9/28/83	679	649	82.6	97.8
1602	84-105A	9/28/84	680	648	82.5	97.8
1766	86-55A	7/28/86	679	648	82.5	97.8
1869	87-62A	7/16/87	679	647	82.5	97.8

Notes:
1. All satellites were launched from Plesetsk by the F-2.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital period in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

Numerical Edge-Codes of Okean-O Satellites

A reply from the USSR State Committee for Hydrometeorology and Control of Natural Environment to an inquiry by Dieter Oslender, of Bonn-Röttgen, West Germany, about the interpretation of the numerical edge code on the APT images received from satellites of the Cosmos 1500 type revealed that the number which appears on line 3, immediately below the gradation wedge, could take one of only 64 possible values. It was shown that, by expressing the value as a 12-bit binary number and selecting the appropriate bits, seven other parameters relating to the status of the onboard instrumentation could be identified in lines 4 through 12.[89]

S.S. Khodkin's reply confirmed that the number on line 1, above the gradation wedge (line 2), is the time in minutes after midnight (Moscow Standard Time) and gave explanations for the other ten

[84] Moscow. 1600 GMT, Sept. 28, 1986.
[85] Daygorodov, G. *Sotsialisticheskaya Industriya*, Moscow, Dec. 6, 1986. p. 1.
[86] *Aviation Week and Space Technology*, Oct. 19, 1987, p. 27.
[87] *Ibid.*
[88] Kettering Group Technical Memo GP8706, Sept. 9, 1987.
[89] Perry, G. E. R.I.G. Newsletter. Leighton Buzzard, England, Sept. 1987. p. 14-15.

numbers which follow the gradation wedge. The onboard time is zeroed automatically every 24 hours or by command. The maximum relative error of satellite time is no worse than ± 5 microseconds in the course of every 24 hours. The error between satellite time and standard time is 0.1 second. The error of the time of resetting to standard time is 0.1 second. The indicated satellite time (in minutes) corresponds to the moment of transition from the level of the black marking field, located above the onboard time display, to the level of the white field.

The last two numbers on lines 4–12 only are significant. These denote the integer and decimal fraction of the telemetry value in volts to a tolerance of +0.2 V. Identification of the parameters being monitored and the ranges of permissible values for these lines were listed in the first table of Khodkin's reply but, without a knowledge of the transfer characteristics, little more than observations of trends is possible. The meanings of some terms, which have been reproduced here as found in the original, are not known.

Line 4 monitors the switching on of the master oscillator. Line 5 has two possible interpretations. One measures the position of the turning platform of the MSU–M. The MSU–M scanner is mounted on a turning platform and can deviate depending on the position of the Sun at angles of ± 25° from the vertical with a step of 5°. Alternatively, line 5 could be an indication of the temperature inside the EA033 back-up instrument. Lines 6 and 8 monitor the operation of the EU2 and EU1 instruments respectively. Line 7 monitors the operation of either the SPM 3 of the primary EA033 instrument or the SPM 4 of the back-up EA033 instrument. Lines 9 and 10 monitor the output powers of the metric (VHF) and decimetric (UHF) radio transmitters respectively. Line 11 has three possible interpretations. It monitors the operation of either the SPM 1 of the EA050 instrument in the 3NP–5NP dm mode or the SPM 2 of the EA141 instrument in the 6NP dm mode. Alternatively, line 11 could be analog telemetry of the primary signal processing unit when it is "on".

The seven possible interpretations of line 12 are listed in sequence as given in Khodkin's reply. They are:

> Telemetry of the body temperature of the device near the motor (level 3): EA050 in the 3NP–5NP dm mode or EA141 in the 6NP dm mode;
>
> Telemetry of the presence of input frequency and IOX pulses of the EA050 in the 3NP–5NP dm mode (level 2); Telemetry of the rotation of the scanning element of the EA141 in the 6NP dm mode (level 2);
>
> Telemetry of the operation of the voltage converter of the EA050 device in the 3NP–5NP dm mode (level 1);
>
> Telemetry of the operation of the voltage converter of the EA141 device in the 6NP dm mode (level 1).
>
> The seventh possibility is analog telemetry of the back-up signal processing unit when it is "on".

The marking field of coloring the channels of the MSU–M is located after the twelve lines of service information.[90]

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[90] Perry, G. E. R.I.G. Newsletter. Leighton Buzzard, England, June, 1988. p. 52–55.

A literal translation of Khodkin's reply for the U.S. Air Force[91] containing at least one typographical error is, in general, in good agreement with the Kettering Group version.

RECOVERABLE PHOTOGRAPHIC SATELLITES

Satellites which produce photographs of individual territories and return the exposed film to Earth operate in the Resurs-F system. This method gives excellent quality photographs, but it has a long cycle for fulfilling consumers' orders. A sub-system solves a number of tasks mainly of a cartographic nature.[92]

A Kettering Group study of recoverable Cosmos satellites with 82.3° inclinations, undertaken before the recent revelations about Resurs-F, concluded that such flights probably served a dual civil/military purpose.[93] By independent consideration of orbital characteristics and received radio transmissions it was possible to distinguish four separate groups.

Satellites in Group 1 had orbital periods between 88.9 and 89.3 minutes, average heights throughout the photographic arc between 215 and 230 km, arguments of perigee between 85° and 115°, 12.9 days mission durations and, when observed, Morse code-like TK recovery beacons.

Although Cosmos 1597, like the others, was announced as an Earth resources mission, no mention was made of it reporting to the Priroda (Nature) Center.

Cosmos 1681 differed somewhat from the others in that it relocated its perigee from an initial argument of 142° to 56°, at the same time raising its orbital period from 88.9 to 89.0 minutes.

Table 20 lists the Cosmos Resurs-F satellites in Group 1 from 1984 through 1987.

TABLE 20.—GROUP 1 RESURS-F SATELLITES: 1984–1987

Cosmos number and designator		Launch date	Apogee	Perigee	Inclination	Orbital period	Recovery date	Life
1557	84-48A	5/22/84	247	211	82.3	89.1	6/4/84	13
1597	84-99A	9/13/84	244	211	82.3	89.1	9/26/84	13
1681	85-80A	9/6/85	226	219	82.3	89.0	9/19/85	13

Notes:
1. All satellites were launched from Plesetsk by the A-2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

Satellites in Group 2 had orbital periods between 89.0 and 89.9 or 90.0 minutes following maneuvers to raise perigee early on the second day, average heights throughout the photographic arc between 270 and 280 km, arguments of perigee between 285° and 335°, 13.9 days mission durations and, when observed, Morse code-like TF recovery beacons.

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[91] FTD-ID(RS)T-1223-87 of the Foreign Technology Division/USAF Systems Command, Nov. 3, 1987.

[92] *Leningradskaya Pravda*, op. cit.

[93] Thomson, G. H. and G. E. Perry. Cosmos Satellites at 82.3°. Journal of Photographic Science, Bath, England, 1988. p. 22–25.

Cosmos 1575 had a mission duration of 14.9 days and Cosmos was unique in having its final argument of perigee at 3°, outside the range quoted above.

Cosmos 1653, Cosmos 1657 and Cosmos 1663 were subsequently identified as participants in the Kursk-85 project.[94]

Cosmos 1653, Cosmos 1657 and Cosmos 1672 were announced as Earth resources missions but no mention was made of them reporting to the Priroda (Nature) Center.

The last two flights of 1987 deserve special mention. Cosmos 1882, at the old 82.3° inclination, flew for 21 days before being recovered, a 50 percent extension to the normal mission duration. On January 10, 1988, Radio Sweden carried a *TASS* report about a new type of remote sensing satellite, capable of surveying an area of one million square kilometers in ten minutes and revealing roads and small houses. This was a reference to Cosmos 1906, with an 82.6° inclination, launched two weeks earlier.[95] Grahn, in Sweden, picked up FM telemetry from Cosmos 1906 on 231.5 MHz, three days after the launch, but the usual shortwave transmission on 19.989 MHz was not heard. After five weeks in orbit, Cosmos 1906 was probably exploded deliberately following unsuccessful attempts at recovery. The fragmentation occurred at 1109 GMT on January 31 and NORAD cataloged 36 fragments (1987-108C-AP) but many more may have decayed before being cataloged. Undoubtedly this was a double blow for the Soviets for not only had they taken the unusual step of proclaiming its role, but also any imagery intended for recovery was lost.

Table 21 lists the Cosmos Resurs-F satellites in Group 2 from 1984 through 1987.

From 1981 through 1983, satellites in Group 3 had orbital periods of 88.8 minutes increasing to 91.55 minutes following maneuvers to raise perigee early on the second day, average heights throughout the photographic arc between 345 and 385 km, 13.8 days mission durations and, when observed, Morse code-like TF recovery beacons. When such flights were resumed in 1986 with Cosmos 1789 a change of inclination to 82.6° was noted together with a reduction in orbital period to 91.2 minutes, with a consequent reduction of height through the photographic arc. Cosmos 1846, with the lower inclination of 82.4° in 1987 adopted a similar regime.

Satellites in this Group achieve complete photographic coverage with triple-interlaced ground tracks resulting in an approximation to a three-day, regular re-visit pattern after every 47 orbits.

Cosmos 1789 and Cosmos 1846 were both announced as having Earth resources missions but neither satellite was said to be reporting to the Priroda (Nature) Center.

Table 22 lists the Cosmos Resurs-F satellites in Group 3 from 1984 through 1987.

Group 4 contains satellites which did not fall easily into any of the three groups described above and which are here considered individually. All of the satellites were announced as having Earth resources missions and only Cosmos 1584 was not identified as reporting to the Priroda (Nature) Center.

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[94] *TASS*, 1245 and 1250 GMT, June 24, 1985.
[95] *Pravda*, Jan. 10, 1988.

TABLE 21.—GROUP 2 RESURS–F SATELLITES: 1984–1987

	Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period	Recovery date	Life
1537	84–17A	2/16/84	273	259	82.4	89.8	3/1/84	14
1572	84–60A	6/15/84	273	259	82.4	89.9	6/29/84	14
1575	84–64A	6/22/84	274	258	82.3	89.8	7/7/84	15
1590	84–87A	8/16/84	270	261	82.4	89.8	8/30/84	14
1591	84–92A	8/30/84	272	259	82.3	89.8	9/13/84	14
1653	85–38A	5/22/85	273	259	82.3	89.8	6/5/85	14
1657	85–44A	6/7/85	274	257	82.3	89.8	6/21/85	14
1663	85–52A	6/21/85	273	259	82.3	89.8	7/5/85	14
1672	85–67A	8/7/85	273	258	82.3	89.8	8/21/85	14
1678	85–77A	8/29/85	272	258	82.3	89.8	9/12/85	14
1708	85–115A	12/13/85	273	257	82.3	89.8	12/27/85	14
1746	86–40A	5/28/86	273	259	82.3	89.8	6/11/86	14
1762	86–51A	7/10/86	273	259	82.6	89.8	7/24/86	14
1768	86–58A	8/2/86	273	259	82.6	89.6	8/16/86	14
1882	87–77A	9/15/86	278	256	82.3	89.9	10/6/87	21
1906	87–108A	12/26/87	277	257	82.6	89.9	1/31/88	dis

Notes:
1. All satellites were launched from Plesetsk by the A–2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Cosmos 1762, Cosmos 1768 and Cosmos 1906, in 1986, had inclinations of 82.6°, prompting speculation that such an inclination had supplanted the long-established 82.3°. However, there have been further flights at both inclinations through June 1988.
5. The 21-day mission of Cosmos 1882 was 50 percent longer than had been usual.
6. Cosmos 1906 was probably destroyed deliberately following failure of its recovery system.
7. Table prepared for the Congressional Research Service by G. E. Perry.

TABLE 22.—GROUP 3 RESURS–F SATELLITES: 1984–1987

	Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period	Recovery date	Life
1789	86–84A	10/31/86	342	322	82.6	91.2	11/14/86	14
1846	87–45A	5/21/87	342	323	82.4	91.2	6/4/87	14

Notes:
1. All satellites were launched from Plesetsk by the A–2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

From consideration of orbital period alone, Cosmos 1582 is a strong candidate for Group 2. However, its height throughout the photographic arc was significantly lower than those of others in that Group and its perigee was located in the northern hemisphere.

The eccentric orbits of Cosmos 1584 and Cosmos 1757 are more characteristic of close-look military photographic reconnaissance missions. The perigee of Cosmos 1757 was lower than normal for a military mission and was located in the southern hemisphere.

Table 23 lists the Cosmos Resurs-F satellites in Group 4 from 1984 through 1987.

USES AND RESULTS OF REMOTE SENSING FROM SPACE

Agriculture

Soviet satellites were to be incorporated into a system of aerospace monitoring of 25 million hectares of desert pasture in Central Asia and Kazakhstan which would commence operation on Janu-

TABLE 23.—GROUP 4 RESURS–F SATELLITES: 1984–1987

	Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period	Recovery date	Life
1582	84–74A	7/19/84	280	253	82.4	89.8	8/2/84	14
1584	84–76A	7/27/84	364	180	82.3	90.0	8/10/84	14
1757	86–45A	6/11/86	392	159	82.3	90.0	6/25/86	14

Notes:
1. All satellites were launched from Plesetsk by the A–2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

ary 1, 1985.[96] On the strength of space photography, sheep grazing in some areas of Kazakhstan was temporarily halted.[97]

Spacecraft imagery had been of assistance to farms in Radekhov Rayon, Lvov Oblast of the Ukraine. Crop yields were increased, the distribution of rodents was easily established and faults in drainage systems were located.[98]

Devices for the teleanalysis of ripening crops, built in Bulgaria, Hungary, the German Democratic Republic and other socialist countries, installed on satellites and the Mir orbital station, would be used in the development of a space system for forecasting harvests.[99]

The collection and processing of aerospace information for farming needs is among the principal responsibilities of a research center called "Agroresursy" (agricultural resources) established during 1986.[100] The space-based agricultural management system called "AIUS-Agroresursy" monitors the condition of crops, soil, rivers and irrigation canals. It collects and processes information received simultaneously from space, aircraft equipped with laboratories and small aircraft, and from ground stations. It assess the general condition of crops, vegetation periods of plants, needs for fertilizer, salinity of soil and purity of water reservoirs with 9798 percent accuracy and, by the year 1900, the system will cover the entire Soviet Union and issue information bulletins for local agricultural managers and farms once every five days.[101]

Forestry

Space images of the southern Urals from a Meteor-Priroda satellite distinguished between coniferous and deciduous forests, both in texture and color.[102]

Geology

Soviet deputy minister of geology Volkov was interviewed in 1985 and referred to photographs of the Earth's surface taken from Meteor and Cosmos satellites and the Salyut 7 orbital station. He said that "hundreds of prospective deposits of various minerals are

[96] *TASS*, 0715 GMT, Nov. 23, 1984.
[97] Moscow, 1415 GMT, Oct. 13, 1985.
[98] Kiev. 2100 GMT, July 17, 1986.
[99] Moscow. 1200 GMT, Aug. 12, 1986.
[100] *TASS*, 0816 GMT, Sept. 2, 1986.
[101] *TASS*, 1114 GMT, Apr. 15, 1986.
[102] Moscow, 2300 GMT, Feb. 28, 1985.

being discovered every year as a result only of space research." [103] Use of space photographs had helped the identification of new ore regions and ore sites, including those in northern Siberia, the Far East, and Yakutiya, and had revealed many dozens of so-called prospective photoanomalies—deep strata with characteristics favorable for formation of oil and gas beds. He said that the cost of space photographs of the Earth's surface was 10–15 times less than aerial photography and that, in the identification of territories for immediate detailed work, the annual savings could be estimated at roughly 30 million rubles.[104]

Satellite photographs helped geologists in Kazakhstan to discover underground resources of drinking water in the Sary-Ishik-Otrau desert. They showed tectonic fissures filled with fresh water. Pictures taken over the Lake Balkhash area also suggested spots where drinking water might be found and space photography had made it possible to detect several ancient river beds concealed by sand dunes which may be of economic value as watering places for stock farmers.[105]

A map of the fluctuation of glaciers based on space images is used in designing hydrotechnical buildings in the mountainous parts of Central Asia.[106]

Large-Scale Integrated Research Programs

Meteor-Priroda and Cosmos satellites have participated in several programs which also involved orbital space stations, aircraft and land and sea based stations as what was described as "storeys" in a multi-tiered system of sensors. Some of these have been described in greater detail in chapter 2 of the first volume of this report, but are mentioned here for completeness.

Anneks-87.—Two Soviet meteorological satellites, the Mir orbital station, an IL–14 flying laboratory and Czechoslovak ground stations took part in an investigation into the level of pollution in the atmosphere over Prague in 1987.[107]

Chernoye More (Black Sea).—Meteor-Priroda and Cosmos 1500 were employed in this experiment which was conducted from August 28 through September 18,1984. The Black Sea was used as a model of the ocean providing a convenient test area for simulating the more important hydrophysical processes. Scientists were also interested in the questions of the interaction between the waters of the River Danube and the Black Sea and the dynamics of the river's delta.[108]

East European Experiment.—In preparation for this experiment, due to be held in the summer of 1988, an international expedition by socialist member nations of Intercosmos practiced methods of remote ecological observations from satellites and aircraft at the Rybinsk Sea reservoir on the upper reaches of the River Volga in the summer of 1987.[109]

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[103] *Argumenty i Fakty,* Moscow, July 2, 1985, p. 4–5.
[104] *Ibid.*
[105] *TASS,* 1922 GMT, Jan. 21, 1986.
[106] Moscow, 1100 GMT, May 27, 1985.
[107] Moscow, 0730 GMT, Sept. 21, 1987.
[108] *TASS,* 1540 GMT, Sept. 4, 1984.
[109] *TASS,* 1010 GMT, Sept. 18, 1987.

Geoeks-86.—This Intercosmos experiment studying ecological and other aspects of forests, agricultural areas and towns in the German Democratic Republic. The Deuben Heath, the area round Leipzig and agricultural areas round Potsdam and Eberswalde were selected as targets. Unspecified "space vehicles" participated in the experiment with aircraft and ground stations.[110]

Gyunesh-84 and Gyunesh-85 (Sun—in Azerbaijani).—The Sheki-Zakataly research ground of the Azerbaijan S.S.R. was used to provide ground-truth for observations made from Salyut 7 in 1984.[111] Natural formations were used as a model to test methods of studying the Earth from space and the experiment was repeated in 1985.[112]

Kursk-85.—During the period from June 19 through 23, 1985, the territory of the Kursk Oblast was used as a scientific testing ground of the Institute of Geography of the Soviet Academy of Sciences for the "study of the dynamics of geosystems by remote methods."[113] In addition to the Salyut 7 orbital station and Meteor satellites, Cosmos 1653, Cosmos 1657 and Cosmos 1663 were specifically identified as participating in the experiment.[114]

The MKF-6 Camera

The multispectral MKF-6 and MKF-6M cameras, manufactured by Kombinat VEB Carl Zeiss Jena, have been used for ten years in the Soviet remote sensing program, as described in earlier editions of this review.

Technical parameters of the MKF-6 space camera cited in a recent paper[115] give the resolving power as 150 line-pairs/mm, the distortion < 3 microns, the frame size as 81 mm x 53 mm, and the ground area covered from a height of 350 km as 200 km x 155 km.

Pictures taken from the Salyut and Mir orbital stations have helped determine more accurately the directions of currents in the Baltic Sea near the shores of the German Democratic Republic.[116]

It was reported that more than 700 Soviet plants and institutions made use of imagery returned from the Salyut 7 orbital station and had helped to save more than 7 million rubles in choosing the best sites for tunnels on the Baykal-Amur railway in the east of the Soviet Union.[117]

NAVIGATION

THE TSIKADA SYSTEM

Replacements of the Cosmos satellites of the civil "Tsikada" navigation system were launched as required during 1984–1987. The civil satellites are replaced less frequently than their military counterparts, suggesting that they offer a lower degree of precision to the user. There is also evidence that the power outputs of these

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[110] ADN, 1436 GMT, July 2, 1986.
[111] *TASS*, 1345 GMT, Sept. 3, 1984.
[112] *TASS*, 1026 GMT, Aug. 13, 1985.
[113] *TASS*, 1245 and 1250 GMT, June 24, 1985.
[114] Vladen. *Sovetskaya Kirgizia*, Frunze, Aug. 18, 1986. p. 2.
[115] Marek, K-H., K-H. John and S. Jähn. *Jena Review*, Jena, D. D. R., 1987. p. 160–163.
[116] Moscow, 1000 GMT, Sept. 3, 1986.
[117] Moscow, 1100 GMT, May 27, 1985.

satellites are allowed to deteriorate to lower levels before replacement is considered.[118]

The operational civil system consists of four satellites in orbital planes spaced at 45° intervals in right ascension. Each plane takes a specific identity number from 11 through 14. Satellites which have been replaced and then subsequently re-activated to provide a back-up service and those which have just been launched and are in the pre-operational check-out phase may take identity numbers of 15 upward. For instance, shortly after launch, Cosmos 1727 had the identity number 16 but assumed identity number 12 on replacing Cosmos 1506 as the operational satellite in that plane.[119] In July 1987 a civil navigation satellite, observed to be transmitting five parameter blocks, was identified as the replaced Cosmos 1383 which had identity number 11 when operational but then assumed identity number 15. This implies that the "temporary" identity numbers are n + 4, where n is the plane identity number for an operational satellite.

All satellites transmit a 6,000-bit navigation message at a rate of 50 baud on a frequency of 150.00 MHz. A near-complete description of that message has been published elsewhere.[120]

Kettering Group observations during 1986 from the Falkland Islands and Western Australia established that the civil navigation satellites transmit continuously.[121]

Table 24 lists the Cosmos satellites in the civil "Tsikada" navigation system from 1984 through 1987.

TABLE 24.—COSMOS SATELLITES IN THE CIVIL "TSIKADA" NAVIGATION SYSTEM: 1984–1987

Payload name	Launch date	Apogee	Perigee	Inclination	Orbital period	Remarks
Cosmos 1553	5/17/84	010	965	82.9	104.9	#11 [1383]
Cosmos 1574	6/21/84	1008	969	83.0	104.9	#14 [1339], COSPAS 3
Cosmos 1655	5/30/85	1016	979	83.0	105.1	#13 [1447]
Cosmos 1727	1/23/86	1016	962	83.0	104.9	#12 [1506]
Cosmos 1791	11/13/86	1013	954	83.0	104.8	#11 [1553]
Cosmos 1816	1/29/87	1011	965	82.9	104.9	#14 [1574]
Cosmos 1861	6/23/87	1000	985	82.9	105.0	Carries RS10 & RS11 amateur radio, same plane as 1727

Notes:
1. All satellites launched by the C–1 booster from Plesetsk.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Numbers preceded by # indicate the identity numbers referred to in the satellites' navigation messages.
5. Numbers in brackets are the Cosmos numbers of satellites replaced by those listed.
6. Cosmos 1861 transmitted a navigation message for only a few days following its launch. For further details refer to the section on Amateur Radio in this chapter.
7. Table prepared for the Congressional Research Service by G. E. Perry.

Cosmos 1383 was nearly two years old when it was replaced by Cosmos 1553, which did not carry Cospas search and rescue equipment (see next section) to replace that onboard Cosmos 1383. The

[118] Daly, P. and G. E. Perry. *Space Communication and Broadcasting*, 1986. p. 51–61.
[119] Daly, P. and G. E. Perry. *Space Communication and Broadcasting*, 1987. p. 379–384.
[120] Wood, C. D. and G. E. Perry. *Philosophical Transactions of the Royal Society of London*, Series A, 1980. p. 307–315. An abridged version of this paper was included as Annex 2 to Chapter 4 of *Soviet Space Programs: 1976–80 (with supplementary data through 1983)*, Pt. 3, p. 1027–1034.
[121] Ibid., Daly, P. and G. E. Perry, 1987.

second launch of 1984, Cosmos 1574, carried the third Cospas transponder and replaced Cosmos 1339 after 28 months. Cosmos 1655, the only launch in 1985, replaced Cosmos 1447 after 26 months but, like Cosmos 1553, did not carry Cospas equipment to replace that onboard the older satellite. Observations made during the early part of 1988 suggest that all three Cospas transponders were still operating, although their host satellites had been replaced as navigation satellites.

The two launches in 1986 were routine replacements for satellites which had been in orbit for 27 months and two and one half years respectively. Cosmos 1816 replaced Cosmos 1574 in January 1987 after 31 months and did not have Cospas equipment to replace that on Cosmos 1574. Cosmos 1861 appeared to have been a replacement for Cosmos 1727 after only 17 months but, as described in the section above dealing with amateur radio, also carried the RS10 and RS11 transponders. It could be that it is an example of in-orbit storage, analogous to the U.S. SOOS (Stacked Oscars On Scout) program and was launched primarily to take the amateur radio equipment into space without the delay of waiting for the need to replace an operational satellite. After several days of check-out, during which it transmitted as a navigation satellite on several occasions, the navigation transmission on 150.00 MHz was placed in the stand-by mode.

At the end of 1987 the four operational "Tsikada" satellites were Cosmos 1791 (13), Cosmos 1727 (24), Cosmos 1655 (31) and Cosmos 1816 (11) in planes 11 through 14 respectively (numbers in parentheses are the number of months each satellite had been in orbit at that date).

Table 25 shows the replacement sequence of the Cosmos satellites in the civil "Tsikada" navigation system in their respective planes and table 26 shows the right ascensions of the ascending nodes for the operational satellites in the system as of January 1.0, 1988.

TABLE 25.—REPLACEMENT SEQUENCE OF COSMOS SATELLITES IN THE CIVIL "TSIKADA" NAVIGATION SYSTEM: 1984–1987

	11	12	13	14
	1383	1506	**1447**	1339
1984	1553			
				1574
1985			1655	
1986		1727		
	1791			
1987				1816
		1861		

Notes:
1. Orbital planes are separated by 450 right ascension of the ascending node.
2. Cosmos numbers immediately below the double ruling at the head of the table indicate the operational status as of Dec. 31, 1983.
3. Cosmos satellites with designations in bold type also carried Cospas search and rescue equipment.
4. Cosmos 1861 also carriers amateur radio transponders RS10 and RS11. It had not replaced Cosmos 1727 as a navigation satellite by the end of 1987.
5. Table prepared for the Congressional Research Service by G. E. Perry.

TABLE 26.—RIGHT ASCENSIONS OF ASCENDING NODES OF OPERATIONAL "TSIKADA" SATELLITES AS OF JAN 10, 1988

Plane:	11	12	13	14
Cosmos	1791	1727	1655	1809
R.A.	226.8	272.4	319.5	0.4

Notes:
1. Planes 11, 12, 13 and 14 are nominally separated by 450 in right ascension of the ascending node, R.A.
2. R.A., is given in degrees.
3. The R.A. of Cosmos 1861 in plane 12 at this time was 271.9°.
4. Table prepared for the Congressional Research Service by G. E. Perry.

GLONASS

By the beginning of 1984 there had been three launches of triple Cosmos payloads in what may be seen as the initial test phase of the Soviet global navigation system, analogous to the U.S. Navstar Global Positioning System program. Only Cosmos 1414, from the first launch, and Cosmos 1491, from the second launch, had maneuvered to stabilize their positions in locations phased at 45° within the same plane. By mid-January 1984, Cosmos 1519 and Cosmos 1520, from the third launch, had maneuvered to produce a 450 separation in a second orbital plane, separated by 120° in right ascension of the ascending nodes, with Cosmos 1520 leading Cosmos 1519, which was crossing the Equator simultaneously with Cosmos 1414, the leading satellite in the original plane. In fact, 1984, with launches of triple payloads into each orbital plane, saw the establishment of a constellation of satellites in three locations phased at 450 intervals in each of two orbital planes spaced 1200 apart. The two sets of locations were offset in phase by 450 so as to produce a geometry providing optimum conditions of simultaneous visibility from a given test site on Earth. Nicholas Johnson pointed out that such a configuration was identical to that employed by the U.S. Department of Defense for their Navstar satellites in August 1980.[122]

More than one satellite can occupy a particular location, suggesting some degree of system-redundancy, and satellites have been known to switch locations. In October 1984, Cosmos 1520 left the leading location in the second plane, and, in the course of four weeks, moved to join Cosmos 1554, 900 behind. It did not remain there but, in mid-1985, following the launch of a triple payload into the other plane, moved forward once more to take up station with Cosmos 1519 and 1555. In September 1984, Cosmos 1491 raised its orbit and left the constellation, presumably having reached the end of its useful life.

At the end of 1985, a new launch profile for the Proton placed its triple payload directly into the 64.80 inclination, with Cosmos 1711 and Cosmos 1712 450 out of phase with each other and 300 out of phase with the original locations.

The Glonass programme suffered a launch failure in April 1987. A software problem with an improved fourth stage of the Proton launch vehicle resulted in Cosmos 1838–1840 being stranded in the elliptical transfer orbit. Cosmos 1883–1885 were successfully

[122] Johnson, N. L. *Soviet Space Programs 1980–1985.* San Diego, Univelt, 1987. p. 81–82.

launched in September. At the end of 1987 only these three satellites and two of the last trio in the other plane were operational and another successful launch was urgently required.[123] A different malfunction of the Proton launch vehicle on February 17, 1988, led to the failure to place Cosmos 1917–1919 into the original plane, but Cosmos 1946–1948 were successfully placed into that plane three months later.

The use of a repeating ground-track pattern is a feature of several programmes within the overall Soviet space programme and is the reason for the adoption of the 675.7 minute orbital period. At the 64.80 inclination, this gives a pattern of ground tracks which repeats itself every eighth day but some 32 minutes earlier in each cycle of 17 revolutions.

Radio transmissions from Glonass satellites present problems for radio astronomers in the 1610.6–1613.8 MHz band. The hydroxyl molecule produces spectral lines, one of which, at 1612.231 MHz, is the dominant emission line for naturally occurring masers around infrared stars. The ITU allocates the band 1559.0–1626.5 MHz to aeronautical navigation with the lower part, 1559–1610 MHz, also allocated to "radio navigation-satellite (space to Earth)." The band 1610.6–1613.8 MHz is also allocated, on a secondary basis, to the radioastronomy service for spectral line observations. Countries are urged by the ITU to take all practicable steps to protect the radio astronomy service from harmful interference when making assignments to stations of other services to which the band is allocated. The U.S. Navstar GPS frequency of 1575.42 MHz falls within the part of the band specifically designated for radio navigation-satellite, but the Glonass range of frequencies from 1602.5625–1615.50 MHz spreads into the part which is also used for radioastronomy.[124] [125]

A hint that the Soviets would shortly reveal details of the Glonass system and its technical characteristics and performance came from Gennadiy Gromov, director of Ausrire, the Soviet Union's principal avionics R&D center in Leningrad.[126] In a paper co-authored with T.G. Anodina, director of automation in the Soviet Ministry of Civil Aviation, it was suggested that the revelation would be made in Montreal, Canada, during May 1988.[127] Until this event, the radio observations at Leeds University had provided the only details of the information in the Glonass transmissions available in the open literature.[128] Dr. Peter Daly contributed the annex to this chapter and the details provided by the Soviets differ from his conclusions only in minor respects. (The manuscript of Dr. Daly's annex was received on February 10, 1988.)

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[123] Daly, P. *Glonass Satellites*, Lecture to The Royal Institute of Navigation, London, Feb. 17, 1988.

[124] Pankonin, V. Interference to Radio Astronomy from Glonass Transmissions in the Frequency Band 1600–1615 MHz. National Science Foundation, Washington, DC, Aug. 1985.

[125] Carter, J. C. Glonass Observations. Haystack Observatory, Westford, Massachusetts, Aug. 11, 1986.

[126] *Aviation Week and Space Technology*, Dec. 14, 1987, p. 125.

[127] Anodina, T. G. International Civil Aviation Organization, FANS/4-WP/70 and FANS/4-WP/75, May 3 and 6, 1988. Fourth Meeting of the Special Committee on Future Air Navigation Systems (FANS), Montreal, May 2–20, 1988.

[128] Ibid., Daly, P.

Table 27 lists the Cosmos satellite launches in the Glonass system from 1984 through 1987.

TABLE 27.—COSMOS SATELLITES IN THE GLONASS NAVIGATION SYSTEM: 1984–1987

Payload name	Launch date	Apogee	Perigee	Inclination	Orbital period	Remarks
Cosmos 1554–1556	5/19/84	19180	19080	64.8	675.7	C.1556 not stabilized
Cosmos 1593–1595	9/4/84	19171	19088	64.8	675.7	C.1594 not stabilized
Cosmos 1650–1652	5/17/85	19171	19089	64.8	675.7	C.1650 not stabilized
Cosmos 1710–1712	12/24/85	19147	19113	64.8	675.7	C.1712 not stabilized
Cosmos 1778–1780	9/16/86	19144	19116	64.8	675.7	
Cosmos 1838–1840	4/24/87	17539	191	64.8	312.2	failure
Cosmos 1883–1885	9/16/87	19154	19106	64.9	675.7	

Notes:
1. All triple payloads launched by the D–1e, Proton, booster from Tyuratam.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Cosmos 1838–1840 failed to reach the desired orbit due to under performance of the Proton fourth stage on the first burn and its failure to re-start at apogee.
5. Payloads in bold type were placed in the plane of the original trio. Other payloads entered a second plane spaced 120° away in right ascension of the ascending node.
6. Table prepared for the Congressional Research Service by G. E. Perry.

SEARCH AND RESCUE

The Cospas-Sarsat system continued to develop from 1984–1987 with progress reports being issued from time to time detailing the launch of a new satellite and the commissioning of new ground stations, and reporting the numbers of incidents and lives which had been saved as a result of the service.

In May 1984, reporting the completion of the third Soviet ground station in Vladivostok, Moscow and Arkhangelsk already being in service, it was expected that the service would be operating at full capacity in 1990. Until that time the system had helped to register 25 shipwrecks and 44 air accidents involving, for the most part, "small fishing boats or private yachts and planes which take to the sea or to the air in any weather and are not always manned by people qualified enough to steer their craft safely in adverse conditions." [129] A later report added that some 200 people had been saved.[130] The station, serving the Pacific Ocean, Sea of Okhotsk, the South China Sea and Sakhalin, was reported as having been established more than eighteen months after the May 1984 announcement.[131]

The seventh session of the coordinating group was held in Leningrad in October 1984. Location of distressed craft was said to be pinpointed with an accuracy of 1 km. More than 100 rescue operations had been carried out and over 250 people had been saved.[132] Representatives of the four founder states (the Soviet Union, United States, France and Canada) adopted a joint "Document on mutual understanding" which stipulated the terms of entry of third countries.[133]

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[129] *TASS*, 0857 GMT, May 30, 1984.
[130] *TASS*, 0857 GMT, June 30, 1984.
[131] *TASS*, 1611 GMT, Jan. 20, 1986.
[132] *TASS*, 0819 GMT, Oct. 2, 1984.
[133] *TASS*, 2108 GMT, Oct. 5, 1984.

The 1 km precision noted above would appear to have been overly optimistic. At the end of 1986, Aleksandr Dunayev, head of Glavkosmos, told journalists that new instrumentation would pinpoint the location of an accident to with 2–3 km and that, up to that time, a precision of only 12 km had been achieved.[134]

The eighth session was held in Seattle, in August 1985. At this meeting, Yuri Atserov, chairman of Morsviazsputnik,[135] said that more than 500 lives had been saved. He said that Britain, Norway, Bulgaria, Finland and Denmark had gradually joined the system and that a decision on the joining of Brazil had been taken at the Seattle session. He said that a new Soviet radio buoy used in the system was on display at an exhibition in Moscow.[136]

The 25th working meeting was held in Moscow in November 1986. It was reported that Britain and Norway had erected ground stations and that Bulgaria and India were expected to join soon. The participants in the system were preparing a draft intergovernmental agreement which would enable the system to be shared by all countries.[137]

The number of persons who had been rescued through use of the system passed the one thousand mark after five years of operation in 1987.[138] At a meeting in Dublin, Ireland, in May 1988, it was reported that the total had reached 1,100.[139]

One of the first adverse statements about the system appeared in *Komsomolskaya Pravda,* which noted that the Ministry of Communications Equipment Industry was "constantly failing to observe the manufacturing deadlines of special radio beacons, or manufactured them to a quality standard that was not very high. As a result, operations to rescue people cost a great deal, each hour of flight costing Aeroflot 700 rubles." [140]

An article giving an account of an operation for rescuing the passengers and crew of an AN–2 airplane, which had crash-landed in a remote area of the Taymyr National Region (Okrug) criticized flaws in the Cospas-Sarsat system which had located the airplane by picking up an emergency signal broadcast by a transmitter which was onboard the plane.[141]

The writer complained that the Cospas-Sarsat system fell far short of being adapted to the needs of the Soviet Union, in that equipment installed in stations for receiving signals from space had not been perfected and did not permit the coordinates of the disaster victims to be computed quickly and precisely. It was claimed that rescue teams usually obtained their information from tracking stations of other countries and that malfunctions occurred regularly in Soviet stations' apparatus.

The writer had formed the impression that "the people responsible for operating the Soviet part of the system were in too much of a hurry to report its commissioning." [142] It was pointed out that

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[134] *TASS,* 1340 GMT, Dec. 4, 1986.
[135] Yuri Atserov retired in Feb. 1988 and was succeeded by Valeriy Bogdanov. (*Ocean Voice.* Inmarsat. London, Apr. 1988, p. 6.)
[136] *TASS,* 0940 GMT, Aug. 7, 1985.
[137] *Izvestiya,* Nov. 20, 1986.
[138] *Aviation Week and Space Technology,* Nov. 30, 1987, p. 71.
[139] Moscow World Service, 2200 GMT, May 27, 1988.
[140] Moscow Home Service, 0500 GMT, June 7, 1986.
[141] *Sovetskaya Rossiya,* Aug. 20, 1987, p. 4.
[142] Ibid.

the potentialities of the Cospas-Sarsat system were not really accessible to Soviet users since the Soviet Union had never produced EPIRBs for the system. It had been fortunate that the crashed AN-2 had carried an emergency transmitter tuned to the satellite's frequency and that the accident had occurred not far from a permanent airfield. The article concluded by posing the question, "But what is to be done by the many travelers who lack even such simple radio sets and whose routes take them thousands of kilometers from dwelling places and roads?" [143]

Oceanographers of the Ukranian Academy of Sciences' Marine Hydrophysics Institute and the Lvov Polytechnical Institute have used the Cospas-Sarsat system for studying ocean currents in the tropical zone of the Atlantic Ocean near the coasts of Suriname, Guyana and Brazil. The system provided from five to seven daily contacts with buoys equipped with special transmitters which had been set adrift from vessels passing through the designated starting points.[144] The experiment was conducted during March 1985 using two LOBAN expendable buoys, released from the scientific research vessel Akademik Vernadskiy. Preliminary estimates showed that the cost of manufacture of a single buoy (5000 to 7000 rubles) and the period of independent functioning (not less than 100 to 150 days) justified their mass use.[145]

Cosmos 1574, carrying the Cospas 3 equipment, was the only satellite in the system to be launched after the end of 1983. For completeness, Table 28 lists the three satellites which carry Cospas equipment. Although all three had been replaced as operational civil navigation satellites, their Cospas equipment was still functioning and filling its role as of the end of 1987.

TABLE 28.—COSPAS SATELLITES: 1982–1987

	Payload name	Launch date	Apogee	Perigee	Inclination	Orbital period
Cosmos 1383	COSPAS 1	6/29/82	1028	989	82.9	105.3
Cosmos 1447	COSPAS 2	3/24/83	1013	959	83.0	104.8
Cosmos 1574	COSPAS 3	6/21/84	1008	969	83.0	104.9

Notes:
1. Apogee and perigee heights in kilometers, inclination in degrees, and orbital periods in minutes.
2. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
3. The Cospas 1, 2 and 3 satellites are in the civilian navigation satellite planes 11, 13 and 14 respectively.
4. Although all three host satellites have been replaced as operational navigation satellites, their Cospas equipment continues to function as of December 31, 1987.
5. Table prepared for the Congressional Research Service by G. E. Perry.

Geodesy and Mapping

GEODESY

The 1987 booklet *Space Technology Serves Economic Needs* includes a section titled "Satellites Size Up the Earth" [146] which opens:

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[143] Ibid.
[144] *Sotsialisticheskaya Industriya*, Moscow, Dec. 2, 1987, p. 4.
[145] Motyzhev, S. V., Yu. I. Bekhterev, N. I. Kiyashchenko, V. L. Kotlyarov and A. G. Karasev. *Issledovaniye Zemli iz Kosmosa*, Mar.–Apr. 1987. p. 12–16.
[146] op. cit., Astachkin, A., et al.

> With the help of satellites it is now possible to establish the coordinates of any point on the Earth's surface, determine more accurately the shape of the Earth and the parameters of its gravity field, and to draw topographic maps of any area.
>
> Space-based geodetic experiments have been conducted in the Soviet Union since 1962 with the help of satellites of the Cosmos series. These experiments are based on simultaneous observations of an orbital spacecraft from several points on the ground. Different parameters of their position relative to the satellite are measured, such as distance to the satellite, the speed at which it changes, and the change in angular orientation.[147]

Illustrations in this section include photographs of the Soviet-made AFU-75 camera for photographing artificial Earth satellites and a high-accuracy laser range finder designed by specialists from countries participating in the Intercosmos program. The text also mentions the SGB camera developed in the German Democratic Republic.

In commenting that methods of space geodesy were constantly being improved it predicted that "new highly accurate instruments will make it possible to study fine geodynamic effects, such as the movement of the Earth's poles and variations in the speed of its rotation." [148]

A second-generation laser telescope designed by the Latvian University, Riga, and the Soviet Academy of Sciences, computer-controlled and equipped with automatic guidance and tracking instrumentation, was brought into operation at the University in October 1987. From the description of "a shaft of green light" it would appear that a neodymium-yttrium aluminum garnet (Nd:YAG) laser is used. A reference to a 60 cm-diameter sphere suggests that its "target" was the U.S. LAGEOS satellite. A precision of 20 cm in a distance of "tens of thousand of kilometers" was claimed. Its purpose was stated to be the study of the irregularity of the Earth's rotation, the shifting of the poles and continental drift, and the monitoring of the Earth's gravitational and magnetic fields.[149]

Cosmos satellites having a specific geodetic role have not been identified by the Soviets, but a sub-set with near-circular orbits close to 1,500 km and orbital periods of approximately 116 minutes, launched by the F-2 from Plesetsk, are considered to be a second generation of geodetic satellites. It would not be surprising if probing with satellite laser range finders revealed that they carried "cats-eye" retro-reflectors.

The Kettering Group identified radio transmissions on 150.30 MHz, discovered by Paul Pitts of Leeds University, England, during January 1985, as originating from Cosmos 1589. The 300 kHz-wide FM transmission was pulse code modulated (PCM) telemetry with a two second frame-duration. With the exception of Cosmos 1732, similar transmissions have been monitored by the Kettering Group from all subsequent satellites in the sub-set. The

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[147] *Ibid.*
[148] *Ibid.*
[149] *TASS*, 1013 GMT, Oct. 9, 1987.

transmissions are not continuous and the presence of an active transmitter on these satellites, in contrast with the purely passive western geodetic satellites, such as Ajisai, LAGEOS and Starlette, would explain the necessity for regular launches to replace satellites whose transmitters have failed or are about to fail.

Since the second generation made its appearance with Cosmos 1312 in 1981, flights have been equally distributed between the initial inclination of 82.6° and the lower 73.6° introduced with Cosmos 1510 at the end of 1983.

The unexpected fragmentation of Cosmos 1823 at 1740 GMT on December 17, 1987, when the satellite was over Angola, Africa, is difficult to explain on any grounds other than as the result of an accidental collision. By May 31, 1988, NORAD had cataloged 66 fragments (1987-20C-BV) and there may still be more to come. Transmissions from Cosmos 1823 were last logged in Kettering on September 22 but monitoring of that satellite was not routine and it may have been operational right up to the moment of fragmentation.

Table 29 lists the second generation geodetic Cosmos satellites from 1984 through 1987.

TABLE 29.—SECOND GENERATION GEODETIC COSMOS SATELLITES: 1984–1987

	Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period
1589	84-84A	8/8/84	1502	1494	82.6	115.9
1660	85-47A	6/14/85	1526	1482	73.6	116.1
1732	86-15A	2/11/86	1526	1480	73.6	116.1
1803	86-94A	12/2/86	1503	1498	82.6	116.0
1823	87-20A	2/20/86	1526	1479	73.6	116.0

Notes:
1. All satellites were launched from Plesetsk by the F-2.
2. Apogee and perigee heights in kilometers, inclination in degrees, and orbital period in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Cosmos 1823 fragmented for no apparent reason on Dec. 17, 1987.
5. Table prepared for the Congressional Research Service by G. E. Perry.

CARTOGRAPHY

Although previous editions of this review have linked mapping with geodesy, it might be that this section would be more appropriately sited with the applications of remote sensing. Its content should, therefore, be considered together with the sections dealing with Soyuzkarta and the MKF-6 camera of this chapter.

Soyuzkarta

Following an unexpected reaction in the American press to an *Izvestiya* article headlined "100,000 dollars for a photograph", V. Yashenko, head of the Soviet Council of Ministers Chief Directorate of Geodesy and Cartography, in an interview for that paper, said:

> There is a very great interest in high-resolution photographs throughout the world. The more accurate data provided by space probes helps to locate land suitable for plowing and irrigation, as well as natural grazing and water resources, and to detect promising geological struc-

> tures bearing oil, coal or gold. Soon after the newspaper article "100,000 dollars for a photograph" appeared, we began to be approached by representatives of Western firms, including American firms. They were mainly interested in two things: what kind of satellite photographs could they purchase from us, and would this kind of trade not be detrimental to the cause of peace? Let me repeat once more: our space photographs are essential for peaceful purposes— or more, no less. We sell satellite photographs to more than 900 civilian organizations. We suggest to all our foreign buyers that they use the photographs in the interests of their countries' national economies, as urged by the new U.N. resolution on the use of space photographs.[150]

The article claimed that the quality of the photographs was "outstanding: they have a resolution of approximately 6 meters." For comparison it quoted the 30 m resolution of Landsat (U.S.A.) and 10 meters black-and-white resolution of SPOT (France). It also quoted from the *International Herald Tribune* and *New York Times* on U.S. government fears lest such photographs might reveal military secrets.[151]

The MKF-6 Camera

High-resolution metric multispectral cameras, such as the MKF-6 and MKF-6M, installed onboard orbital stations such as Salyut or Mir, collect the desired data economically and with a high content of geometric, as well as thematic, information. Metric multispectral photography (MMP) has, for more than ten years, been widely employed for topographic and thematic mapping, especially in long-term assignments. Today, topographic maps at scales between 1:50,000 and 1:100,000 can be produced through space-borne MMP. MMP can be employed very efficiently to explore geological structure and seismotectonics, identify zones of subsidence, register land use patterns, derive subaquatic profile of off-shore areas, monitor waters and map other detail features.[152]

After digitization, multispectral photographs can be processed and classified by computers and used for computer-aided mapping in the same manner as with scanner data. Digitized with 25 micron pixel-spacing, an MKF-6 scene has a statistical information content of approximately 170 megabytes.[153]

> MKF-6 photographs taken from about 250 km above ground (original scale 1:2,000,000) have in the four visual spectral ranges (360 to 680 nm) a ground resolution of about 10 m for high contrast linear and about 15 m for isometric (patchy) objects. In the near infra-red channels (700 to 890 nm) the resolutions are 20 or 30 m, respectively. From analytical aero-triangulation using a 1:25,000 control net and considering Earth curvature and refraction, linear

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[150] *Izvestiya*, Oct. 31, 1987, morning ed.
[151] *Ibid.*
[152] op. cit., Marek, K-H., K-H. John and S. Jähn.
[153] *Ibid.*

> geometric accuracies (r.m.s. distance errors) of about ± 30 m throughout the image scene were derived. Consequently, space MKF–6 photographs are suitable for photogrammetry at map scales of 1:100,000 and, in part, even at 1:50,000. . . . In particular, exposures made in the 640–680 nm and 790–840 nm channels are suitable for the comprehensive interpretation of all kinds of topographic features. Remarkably, additive colour presentation does not significantly add to the accuracy of such topographic interpretations.
>
> Because of their high metric accuracy, MMP images are fairly easy to fit into existing topographic maps, which makes efficient computer-aided revision of different map series or data banks practicable.[154]

SPACE MANUFACTURING

Professor Konstantin Feoktistov, the veteran cosmonaut, in a New Year's interview in 1984 stated that:

> Thanks to the long-duration missions of the Salyut 6 and Salyut 7 stations we can now definitely say that in orbit it is expedient to organize a whole range of production facilities, for example, to obtain certain semiconductor materials, medicines and so forth. . . . Workshops in weightless conditions are no longer a fantasy. . . . It is now known precisely which kinds of materials and alloys it is expedient to make in orbit.[155]

Details of materials processing and other materials and medical/biological experiments have been given in chapters 2 and 3 on experiments on the Salyut 7 and Mir orbital stations in part 1 of this review and will not be repeated here. This section will confine itself to similar work carried out with automatic satellites of the Cosmos series. This new development in the construction of orbital production complexes began in 1985 with the launch of Cosmos 1645 which carried an automatic technical laboratory and introduced a new word, "materiology" into the vocabulary.[156] Tests were conducted with the Splav-2 and Zona apparatus, designed to obtain semiconductor materials by different methods.[157]

Since then, similar flights have come at a rate of one per year. The launch announcement for Cosmos 1744, in 1986, noted that its purpose was "to continue research in materials study." [158]

The launch announcement for Cosmos 1841 in 1987 commented that it carried apparatus for continuing work started on Cosmos 1645 and 1744. It continued:

> The 14-day flight schedule provides for the carrying out of experiments in obtaining semiconductor materials with improved properties and particularly pure biological preparations in conditions of microgravitation. After the sched-

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[154] *Ibid.*
[155] Gubarev, V. *Pravda*, Jan. 1, 1984, p. 3.
[156] *TASS*, Apr. 17, 1985.
[157] Avduyevskiy, V. S., and L. V. Leskov. *Zemlya i Vselennaya*, Sept.-Oct., 1987. p. 6–11.
[158] *TASS*, May 22, 1986.

ule of research has been completed, the test samples obtained on the satellite will be delivered to Earth.[159]

Further details of the payload of Cosmos 1841 were revealed following its recovery.[160] After stating that "in zero-gravity conditions the admixtures can be withdrawn literally by the molecule to produce superpure substances" the report went on to say:

> Medicines for treating the immune system are very important. One such preparation, thymosin, can be produced from the thymus gland in a laboratory but with great losses and some impurities.
>
> Specialists have long set their eyes on space laboratories. . . . It [Cosmos 1841] returned to Earth at 0720 GMT on May 8. Less than eight hours later the various preparations from the satellite were at the Institute of Biomedical Technology in Moscow. They were produced in the Kashtan automatic unit, which experimented with thymus hormone purification. Alpha-1-Thymosin was thus produced.
>
> Another orbital-produced preparation of the interferon type is used for the treatment of viral and tumor diseases.[161]

Glavkosmos promotional literature gives details of the Foton [162] spacecraft (initially referred to as the Cosmos spacecraft) and the Zona, Splav-2 and Kashtan facilities. These are reproduced verbatim below.

THE FOTON

Spacecraft "Foton" is a retrievable carrier that can accommodate microgravity experiments in the field of material processing or biotechnology intended to obtain different materials with new or improved features.

The flight opportunities for 1990 are available.

Basic data on "Foton" flight

1. Flight duration: 14–30 days
2. Payload weight: up to 500 kgs
3. Payload capsule volume: up to 4.7 m^3
4. Average daily energy supply - 400 watts
5. Peak energy supply (1.5 hour a day - maximum) - 700 watts
6. Orbital parameters: apogee - 300-400 km
   perigee - 220–250 km
   inclination - 62.8°
7. During the flight the customer is supplied with the telemetry data and with an opportunity to form control commands.
8. The facility is returned to the customer within 24 hours after the landing of the payload.

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[159] *TASS*, 1017 GMT, Apr. 25, 1987.
[160] U. S. S. R. Space Bulletin SB15, *Novosti Press Agency*, London, July 22, 1987, p. 3.
[161] *Ibid.*
[162] Alternatively spelled Photon.

"Zona" Facility

The "Zona" facility is designed for the manufacturing of crystal materials using a zonal melting technique.

The process is conducted in a sealed quartz ampoule.

The melting through the narrow zone in a crystal material is made by the electric heater. During the experiment the ampoule with its content is being moved by the precision electromagnetic drive. The electric control system automatically maintains with a high precision the given level of the heating-up temperature and the rate of the sample's shift.

The facility can be fitted with the relevant heaters with due account to the material being processed. At the customer's request the zonal melting might be conducted in a constant magnetic field.

In case of an experiment on-board the spacecraft the down-link is made possible allowing to transmit back to the Earth the data related to the technological process parameters. At the same time the on-board registration of the micro-loads acting upon the facility is provided.

Zona Facility—Technical Performances

Heater temperature, °C	500–1200
Given temperature maintenance error, °C	± 1
Melting through zone time preceding the drive initiation, minute	20–120
Shift rate, mm/h	1–15
Shift rate control error, per cent	± 1
Shift drive pace, mm	60
Maximum sample dimensions:	
—diameter, mm	15
—length, mm	110

"Splav-2" Facility

The "Splav-2" facility is intended to manufacture on-board the spacecraft the materials by the three-dimensional and directional crystallization techniques, gaseous and liquid-phase epitaxy.

The facility is made up of technological and electric segments. During the pre-launch ground preparation 12 metallic capsules are installed in the technological segment inside of which there are the quartz ampules with the materials samples.

The capsules are placed one by one into the furnace with the aid of a special device. The crystallization process is being fulfilled provided the capsule is completely stable, the latter being extremely important factor in microgravity.

For each capsule the technological processing mode could be assigned, e.g., heating-up temperature, melting duration under this temperature, cooling down rate (two different rates and the temperature of the transfer from one rate to another might be assigned). This data is coded on a special punch plate provided for all capsules. The given technological mode is maintained with a high precision by the automatic control system.

In case of an experiment on-board the spacecraft the down-link is made possible allowing to transmit back to the Earth the data related to the technological process parameters. At the same time the

on-board registration of the micro-loads acting upon the facility is provided.

"Splav 2" Facility—Technical performances

Heater temperature, °C	500–1050
Cooling down rates, °C/h	2.8; 5.6; 11.3; 22
Temperature maintenance error, °C	± 3
Maximum temperature gradient, °C/cm	140
Capsule's exterior diameter, mm	20
Thermal zone length, mm	150

"Kashtan" Facility

The "Kashtan" facility is designed for the separation and purification of biologically active substances in microgravity by an electrophoresis technique in a free stationary state liquid. In particular, either isoelectric focal pointing or zonal electrophoresis is made available.

The biocomponent separation process takes place in a thermostatic electrophoresis device of a special configuration allowing to subdivide the general volume of the chamber into 49 isolated cells. Thus the stirring of different fractions is prevented.

At the customer's request the separation process might be registered on a photographic film. However in this case the electrophoresis device is not thermostatically controlled.

In case of an experiment on-board the spacecraft the down-link is made possible allowing to transmit back to the Earth the data related to the technological process parameters. At the same time the on-board registration of the micro-loads acting upon the facility is provided.

"Kashtan" Facility—Technical performances

Electrode voltage, V	500–5000
Separation chamber length, mm	1200
Cross-section of the separation chamber, mm^2	5x5 or 10x5
Separation chamber capacity, ml	35 or 70
Single cell capacity, ml	0.7 or 1.4
Thermostatic control temperature, °C	5–25
Process registration rate on a photographic film, exposure/minutes	1

Additional details on Foton were provided in an earlier Glavkosmos publication.[163] The supply voltage was given as 27 + 4 V. The gas temperature and pressure inside the hermetically sealed section were stated to be from 0 to 40°C and from 46.66 to 151.98 kPa (350 to 1140 mm Hg) respectively. Maximum electric current consumption of the scientific equipment, taken from the main supply, was given as 25 A for continuous operation and 50 A for pulses not exceeding 200 ms duration. The somewhat loose employment of the term "power" to mean either current, in amperes, or power, in watts prompted an inquiry to Jardines as to the type of source of

[163] Space Station "Cosmos", Scientific Equipment, Basic Ratings and Technical Requirements. Glavkosmos. Supplied by Jardine Interplanetary Ltd., London.

electrical power and brought the response that "Cosmos [sic] has solar panels, hence it can carry chemical batteries sufficient to supply 400 W power for a 30-day mission" and that "chemical batteries and solar cell arrays are used for power supply." [164] It was also stated that:

> The required precision of the adjustments of the scientific equipment including fields of view, external mounting of certain elements outside the flight configuration on special rods has to be guaranteed; the arrangement of the scientific equipment according to its mass has to be determined for each completing module, whereby mass, centering, inernational, aerodynamic and other parameters of the spacestation are to be taken into account within such limits as guarantee the experiment.

The radio control system of the orbital parameters localizes the spacecraft with a precision of ± 17.57 km on the orbit, ± 0.95 km in height and ± 0.63 km in lateral direction.

The frequency of channel interrogation of the radio telemetry system is 100 Hz in the direct transmission mode at 3 Hz in the registration, or recorded, mode.

The scientific equipment is operated by an automatic control system and can accept single commands given during radio communication sessions, programmed commands given by the control system at particular times, or by "Start of DT" and "End of DT" commands given by the control system, characterizing the direct transmission operation mode of the radio telemetry system. The commands are given as 27 V impulses of positive polarity, of 0.09–0.8 s duration within a control circuit maximum current load of 0.8 A. The minimum interval between commands is 32 s. Up to ten single commands for the scientific equipment can be given as closing impulses for unfed relay points with closing durations of the contacts between 0.09 and 0.8 s, where the current of the contact circuit must not exceed 0.8 A. The scientific equipment must retain operating capability should the control logic become damaged and permit repeated reception of one single identical signal.

Stringent operational requirements for storage and transportation are specified.

> The scientific equipment must function after a 2.5-years storage in adequate package or together with the space station in heatable storage rooms at an air temperature between 5 and 30°C and a relative humidity from 30 up to 80 percent. An air temperature increase up to 35°C and a relative humidity up to 90 percent for 60 days during a year's period is allowed.
>
> In the storage period adjustment work on the scientific equipment is allowed once per year.
>
> The scientific equipment must retain its operativeness under outdoor conditions at temperatures from -40 up to -50°C at a relative humidity from 20 to 80 percent for a period of three months.

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[164] Kovalyova, M. Jardine Interplanetary Ltd., London. Private communication.

The scientific equipment must retain its operativeness after:

(a) transportation together with the space station:
10,000 km railway transport;
2,000 km transport by heavy goods vehicle;
(b) transport in adequate correct package:
up to 10,000 by railway
cargo plane transport—unlimited distance;
heavy goods vehicle transport up to 2,000 km.

In the cargo plane pressure drop down to 20 kPa (150 mm Hg) is allowed for a period of 15 hours.

Comprehensive data relating to low frequency random vibration and shock are given, covering transportation, launch and landing phases.

Conditions during orbital flight, under which normal functioning of the scientific equipment is required, are specified both for equipment mounted in the hermetical sector and on the exterior of the spacecraft:

Hermetical section:
weightlessness;
air atmosphere (oxygen up to 2 percent, helium up to 0.01 percent)
pressure from 46.66 to 151.987 kPa (350 to 1140 mm Hg)
temperatures from 0 to 40°C;
relative humidity up to 80 percent
radiation ionization:
cosmic radiation with an intensity of 0.055 rad/day;
solar explosions of 50 rad during the whole period of the flight

Externally mounted:
weightlessness
deep vacuum 10^{-9} mm Hg;
temperatures from -50 to +150°C;
radiation ionization:
cosmic radiation 51.04 rad/day;
solar explosions of 3.7×10^4 times during the whole period of the flight

The scientific equipment, installed in the hermetical section, is exposed to a short-term pressure drop (down to 40 mm Hg) and to air temperatures between −40 and +60°C during the parachuting and landing phase.

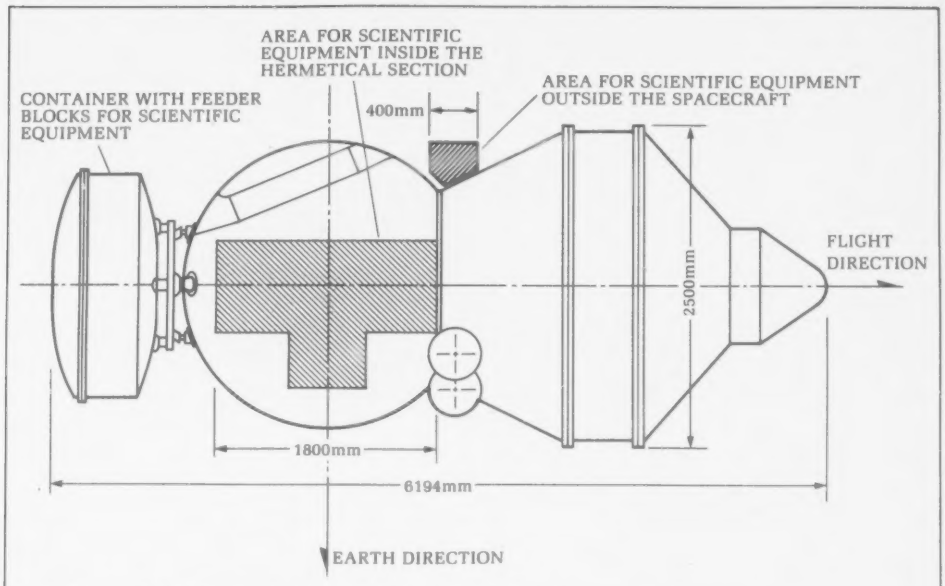
Figure 20 is based on the Glavkosmos publication.

Table 30 lists the microgravity materials processing satellites in the Cosmos series from 1984 through 1987.

Conclusion

A tabulation of the current status and unsolved problems for different complex systems in "Directions of Space Industrialization," published in 1985, provides an overview of topics considered in the

Figure 20.—Foton



Foton Spacecraft for Microgravity Materials Processing. All dimensions are in millimeters. Based on illustration from Glavkosmos.

TABLE 30.—MICROGRAVITY MATERIALS PROCESSING COSMOS SATELLITES: 1984–1987

	Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period	Recovery date	Life
1645	85–29A	4/16/85	390	215	62.8	90.6	4/29/85	13
1744	86–36A	5/21/86	372	219	62.8	90.4	6/4/86	14
1841	87–37A	4/24/87	381	217	62.8	90.5	5/8/87	14

Notes:
1. All satellites were launched from Plesetsk by the A–2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

previous sections.[165] As might have been expected, the status of work along different lines of space industrialization was at different stages. Some space systems were already widely in use in the national economy of the Soviet Union and had a quite high technical-economic efficiency. In others, theoretical and experimental research was being conducted over a wide front, whereas those in a third category were still in the stage of active research planning.

Despite the different technical levels of solution of specific problems in the industrial exploitation of space there were several general problems whose successful solution would profoundly influence progress in all the directions that were mentioned. These included

[165] Grishin, S. D. and L. V. Leskov, *Zemlya i Vselennaya*, May–June, 1985, p. 65–68.

the development of promising transportation-power systems, highly efficient and economical power converters and the development of optimum space technology methods.[166]

The first complex system considered was that of space information systems. Seven directions were listed: space communication systems, satellite meteorology, satellite navigation, space monitoring and preservation of the environment, space geography, space mapping and exploration for minerals, and marine fishing. Their current status was described as "developed and used in space systems for national economic purposes." Unsolved problems listed were the development of comprehensive data systems, banks of scientific and technical data with use of space systems, and increase in efficiency of economic use of space data systems.[167]

The second complex system, space construction and production, was sub-divided into three topics. The current status of the first of these, technology of assembly and erection work in space, noted that practical work had begun in space with the welding experiments on Soyuz 6 and Salyut 7. The development of complex of equipment and technical apparatus for use in space for assembly and erection of large structures were listed as unsolved problems.[168] Production of new and improved materials in space was the second topic considered and the current status noted that technological experiments had been carried out on piloted and automatic space vehicles and that unsolved problems were the formulation of scientific principles of space production and the development of onboard technical complexes for production of materials.[169] The current status of the third topic, use of extraterrestrial resources, was given as long-range research and optimization of transport-power systems was listed as the unsolved problem.[170]

The third complex system was the production of high energies in space and was considered under three headings. The first of these was solar power satellites (see chapter 5, part 1). The current status was said to be long-range research and testing power transformation systems, while the development of highly efficient and economical power transformers, transport systems, and erection methods were listed as unsolved problems.[171] Space optics and power transmission lines, the second heading, had long-range research and the testing of components as its current status. Unsolved problems were the development of light film concentrators, methods for their assembly, development of space transportation systems and optimum construction of systems for transmission and use of energy.[172] The final heading, promising space transportation systems, once more had long-range research as its current status, together with the checking of principles for constructing new space transportation systems. Its unsolved problem was the changeover from thermochemical methods for generating thrust to new principles for constructing space transportation systems.[173]

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[166] *Ibid.*
[167] Ibid.
[168] Ibid.
[169] Ibid.
[170] Ibid.
[171] Ibid.
[172] Ibid.
[173] Ibid.

Although the Soviet Union may have been slow in capitalizing on the economic benefits of its space technology, there is no doubt that they are now fully aware of such benefits and are pursuing an active program of research to profit still further from their considerable expertise, even to the extent of embarking on initiatives to exploit their products commercially for foreign customers.

CHAPTER 3 ANNEX—ORBITAL AND COMMUNICATIONS ASPECTS OF THE SOVIET UNION'S GLONASS NAVIGATION SATELLITES

Historical Perspective

Global satellite navigation systems have been under development by the United States and the Soviet Union since the 1970s although both nations already operated and, in fact, still operate a dual-frequency VHF satellite navigation system in near-polar, low Earth-orbit (U.S. Transit and Soviet Tsikada) providing limited time access on a world-wide basis. The U.S. NAVSTAR GPS system saw its first launch in 1978; the Soviet Union's GLONASS system [1] was inaugurated four years later. GLONASS satellites are launched three at a time from the Tyuratam space center into near-circular orbits with a period of around 11.25 hours at a height of 19,100 km and inclination of 64.8°. Successful launches are followed by an announcement within a day or two in Pravda giving basic details of the mission. There have been ten launches since the first one in 1982, all of them successful except the one in April 1987 where the satellites failed to reach final orbit because of a malfunction of the fourth stage of the Proton launch vehicle. Table 31 presents the international identifiers, Cosmos numbers and GLONASS numbers of all known launches since the first one in 1982; all triple launches have taken place into one of two orbital planes (referred to in the table as planes A and B) separated by 120°.

TABLE 31.—TRIPLE GLONASS LAUNCHES

Launch	International designator	Cosmos	GLONASS	Plane
1	1982-100A,D,E	1413 1414 1415	1 2 3	B
2	1983-84A,B,C	1490 1491 1492	4 5 6	B
3	1983-127A,B,C	1519 1520 1521	7 8 9	A
4	1984-47A,B,C	1554 1555 1556	10 11 12	A
5	1984-95A,B,C	1593 1594 1595	13 14 15	B
6	1985-37A,B,C	1650 1651 1652	16 17 18	B
7	1985-118A,B,C	1710 1711 1712	19 20 21	A
8	1986-71A,B,C	1778 1779 1780	22 23 24	B
9	1987-36A,B,C	1838 1839 1840	25 26 27	A
10	1987-79A,B,C	1883 1884 1885	28 29 30	A

Notes:
1. Status as of end of Dec. 1987.
2. Satellites in launch no. 9 failed to achieve the desired orbit.

[1] Dale, S. A. and P. Daly. Recent observations on the Soviet Union's GLONASS navigation satellites. IEEE PLANS '86 (Position Location and Navigation Symposium), Las Vegas, Nov. 4–8, 1986. p. 20–25.

Each launch aims to produce a final stable near-circular inclined orbit at a distance from the Earth's center of about four Earth radii. Of the first seven launches only two of the three launched satellites achieved such an orbit; the third satellite remained in an orbit without ground-track repeat and was not observed to transmit.[2] Since then both successful launches (launch 8 and launch 10) have resulted in a stable orbit for all three satellites, which have also transmitted full navigation messages and can therefore be regarded as fully-fledged members of the pre-operational system.

It is also a normal feature of the present system for a launch to occur only when the number of functioning satellites has fallen or is about to fall below the number required for adequate testing of the system. This number cannot be stated with absolute precision since it depends on the orbital planes of the remaining satellites. However, a reduction of available units to any number less than four is likely to act as a precursor to a new launch.

PURPOSE OF GLOBAL SATELLITE NAVIGATION SYSTEMS

The aim of both NAVSTAR GPS and GLONASS is to provide high-precision position-fixing and time-reference capability on a world-wide and continuous basis to users on the Earth's surface, on land and at sea, in the air and also in space itself. Under the control of highly stable onboard frequency references (clocks), timing signals (epochs) and data are transmitted simultaneously from a number of satellites. The observer makes time-of-arrival measurements to three satellites, at the same time using the received data to compute the position of the satellites. Given a synchronized time reference, the observer can then, in principle, solve three range equations for his three unknown position coordinates. In practice, the observer will not normally have a synchronized time reference and will therefore choose to "pseudo-range" to four satellites instead of three, using the fourth measurement to compute his instantaneous time error.

DUAL ROLE OF GLOBAL SATELLITE NAVIGATION SYSTEMS

The primary justification for the provision of a global, continuous and precise satellite navigation system is military in that national governments are likely only to allocate the enormous financial resources required to implement such a system on the grounds of defense and national security. However, as has already been seen in the case of Transit and Tsikada, a role for civil use of the systems available has also been deemed acceptable. Both NAVSTAR GPS and GLONASS therefore offer a navigation facility available to the military and civil user. For obvious reasons the military payload is designed to produce a much higher degree of precision than the civil.

ORBITAL CONSIDERATIONS

For a given number of satellites in the final operational system, the choice of orbital planes and phases within the plane is constrained to ensure visibility of four well-located satellites on a con-

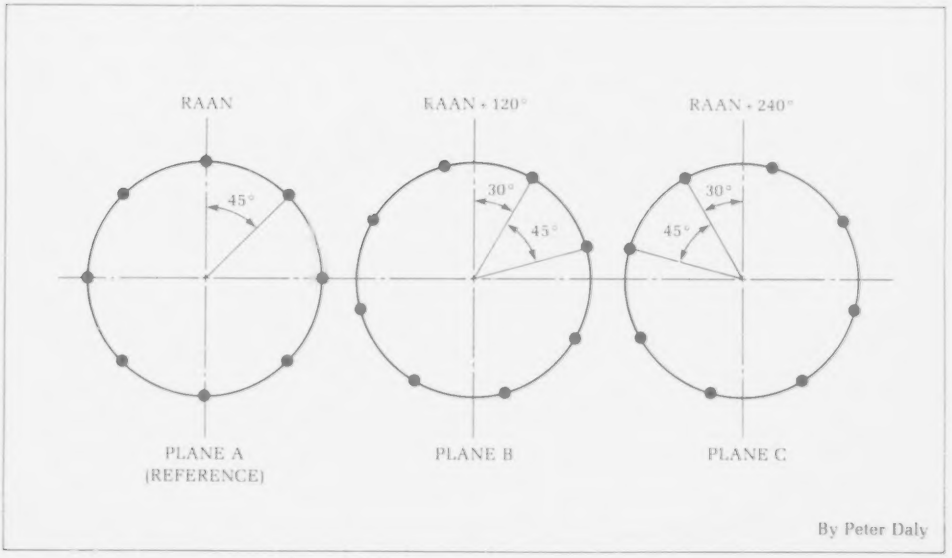
[2] Only one satellite from the first launch achieved the stable orbit. Ed.

tinuous global basis. A common approach is to adopt a small number (3 or 6) of equally separated inclined orbital planes with a number of satellites distributed equally in phase around each plane and with an offset in phase between planes. It is also possible to augment this approach with a number of satellites in the geostationary arc.

GLONASS ORBITAL PLAN

According to the available evidence, it is reasonable to postulate that the GLONASS satellite navigation system foresees an operational configuration of 24 satellites with eight satellites in each of three orbital planes separated in Right Ascension of the ascending node (RAAN) by 120°. Taking plane A with RAAN around 73° on day 250, 1987 as reference, planes B and C have RAANs of 193° and 313° respectively. The situation is shown in figure 21 where the separation in argument of latitude or orbital phase in the plane, is a multiple of 45°. However, as the figure shows, there is a displacement of +30° and −30° for satellites in planes B and C respectively with reference to plane A. The convention used in the figure assumes phase angle measure clockwise and satellite direction of travel in the plane anti-clockwise as shown. Relative positions of satellites remain very stable over long periods because they have very much the same, small rates of change of RAAN, amounting to about −0.03° per day for near-circular GLONASS orbits.

Figure 21.—GLONASS Orbital Plan



All satellites have the same nominal orbital period of 675.73 minutes with longitude change of 169.41°W each orbit. This orbit produces a ground-track repeat every 17 orbits lasting eight whole days less 32.56 minutes. This diurnal offset of dT = 4.07 minutes from a full 24-hour day coincides with that of NAVSTAR GPS and

is very nearly the difference between a solar and sidereal day (3.93 minutes). This implies that each complete day less dT minutes a satellite performs 17/8 orbits or two whole revolutions plus an additional 1/8 revolution, equivalent to 45°. It follows that two satellites in the same plane but separated by 45° in orbital phase, appear at precisely the same position on successive days less dT minutes. During that interval, the Earth has rotated very nearly 360° with the result that the ground-based observer sees both satellites at the same point of azimuth and elevation. Over a ground-track repeat interval of eight days then, all satellites in the same plane with separations of 45° appear in turn at the same position at intervals of one day less dT minutes. After eight days, the whole cycle naturally repeats.

Any ground observer with a high-gain antenna correctly pointed can expect that once any satellite in the plane passes through the beam, all others in the plane will do so on successive days. The advantages for ground controllers with very large antennas is obvious—no repointing is required to access a satellite so long as the controller is prepared to wait for a maximum of eight days. In addition, the exchange of telemetry or telecommand can more easily be protected against unwanted operators.

By examining the phases of satellites in the other planes B and C, it becomes apparent that these satellites will also appear at the same position as the reference satellite in plane A within the same eight-day period. This arises because the time taken for the Earth to rotate through the angle 120° separating planes A and B is the same as the time taken by a satellite in that plane with phase +255° to travel round to the same position as the reference satellite. The Earth rotates through 120° in 478.69 minutes, very nearly eight hours, which corresponds almost exactly to 17/24 of a GLONASS orbital period or 255°. The same argument holds for plane C at 240° separation for a satellite at phase +150° (or twice 255° less 360°). The angular separation of 45° within the plane together with the angular phase differences of ±30° between planes ensures that, in an eight-day period, all 24 satellites will pass through the position with the reference sub-satellite location.

The above argument holds for any valid pointing angle. Once an antenna is pointed at any satellite in the system, all others will, in time, pass through the main beam. For any location, the azimuth and elevation for a particular track have to be computed over an eight-day period, following which suitable pointing angles and time may be chosen by the observer for the reference orbit and satellite. This argument has assumed a near-perfect circular orbit and precise orbital spacing and timing. However, some flexibility in the argument is allowed in these terms since the viewing angle of even the largest ground antenna at L-band exceeds 1° (antenna diameter ~13.5 m) during which time a satellite will remain in the beam pattern for around 2 minutes.

In summary, table 32 gives the number of days, hours and minutes following the reference day and time, D_0, after which any satellite (n = 0,1,2...7) in the above system coincides with the satellite in the reference position in plane A.

For example, a satellite in plane B at relative phase of +75° would reach the position of the reference satellite at phase 0° in

TABLE 32.—GLONASS EIGHT-DAY CYCLE

Plane	Phase (degrees)	Day	Hours	Minutes
A	45n	D_n	0	$-n.d\overline{T}$
B	255 + 45n	D_n	8	$-(3n + 1)d\overline{T}/3$
C	510 + 45n	D_n	16	$-2(3n + 1)d\overline{T}/3$

plane A in approximately 4 days, 8 hours less 17.6 minutes. As has already been stated, the pointing angles for the reference position depend on the location and must be computed at least once.

MANEUVERING IN ORBIT

Once a satellite is established in a stable orbit with ground-track repeat, it may still sometimes be necessary to move the satellite within the orbital plane to a new position. This may occur for example when one satellite fails and is to be replaced by another in the same plane. Maneuvers to change the phase of a satellite in orbit begin by firing the onboard thrusters at apogee where the velocity vector is at right angles to the radius vector to take the spacecraft into a slightly eccentric orbit with altered period in such a way that the spacecraft gradually falls behind or moves forward from (depending on the direction of thruster firing) its initial position. After an integer number of orbits, the required position in phase is reached and a reverse firing of thrusters of exactly the same magnitude as the first ensures a new, stable and circular orbit. The geometry of the two orbits is shown in figure 22.

Taking the semi-major axis of the near-circular orbit as a and that of the eccentric orbit as $a - da$, then the eccentricity of the new orbit is $e = da/(a - da)$. The change in orbital period $d\overline{T}$ referred to the period of the circular orbit is found from Kepler's third law to be

$$d\overline{T}/T = 3da/2a = m/360n$$

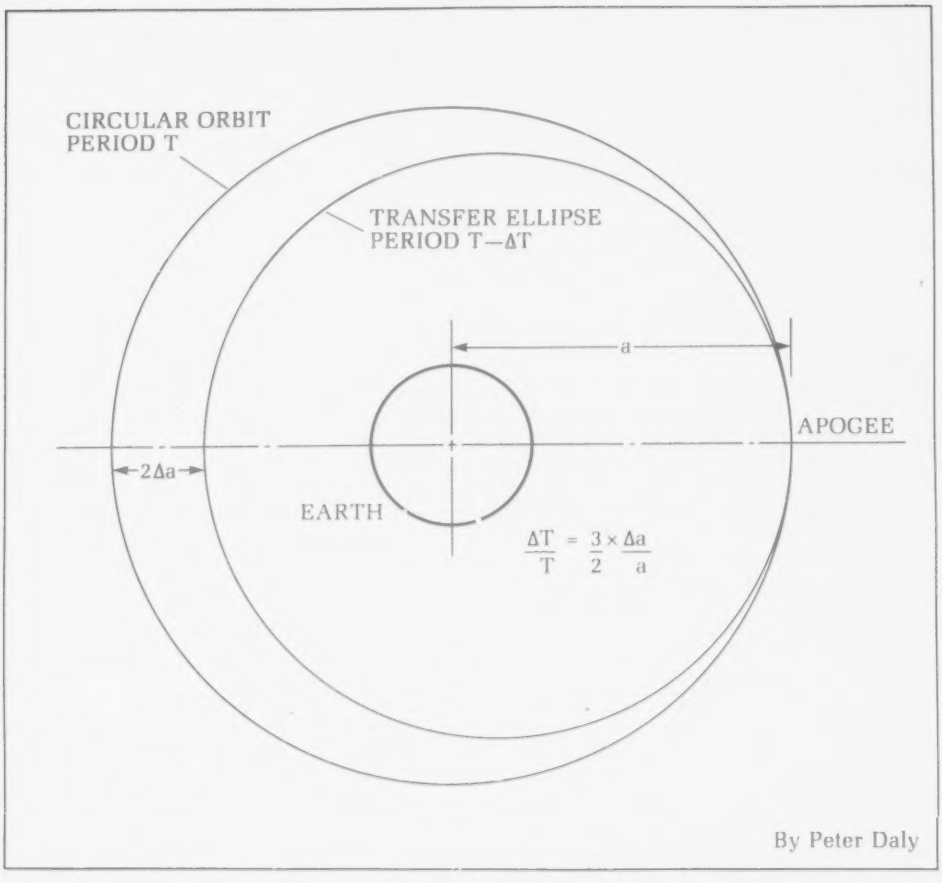
where n is the integer number of orbits to bring the satellite to the position in the circular arc m° from its starting point.

In the manner described above, Cosmos 1885 was given a velocity change on September 21, 1987, so as to decrease its period by almost eight minutes and then to complete 21 eccentric orbits, allowing the spacecraft to accomplish the 90° phase movement in ten days. It is clearly demonstrated that the Soviet GLONASS satellites are capable of rapid maneuvering within the orbit. The spacecraft also have enough fuel onboard to accomplish maneuvers several times—Cosmos 1779 has already traversed 45° of arc on three separate occasions. Clearly spacecraft in the orbital arc which fail can quickly be replaced by another spacecraft. This flexibility would give GLONASS an advantage during the operational phase where one would expect in-orbit spares to be in place and ready to cover for any malfunctioning units.

CURRENT OCCUPATION OF ORBITAL SLOTS

As of the end of 1987, no GLONASS satellite had yet been launched into plane C. Using the satellite Cosmos 1884 (GLONASS

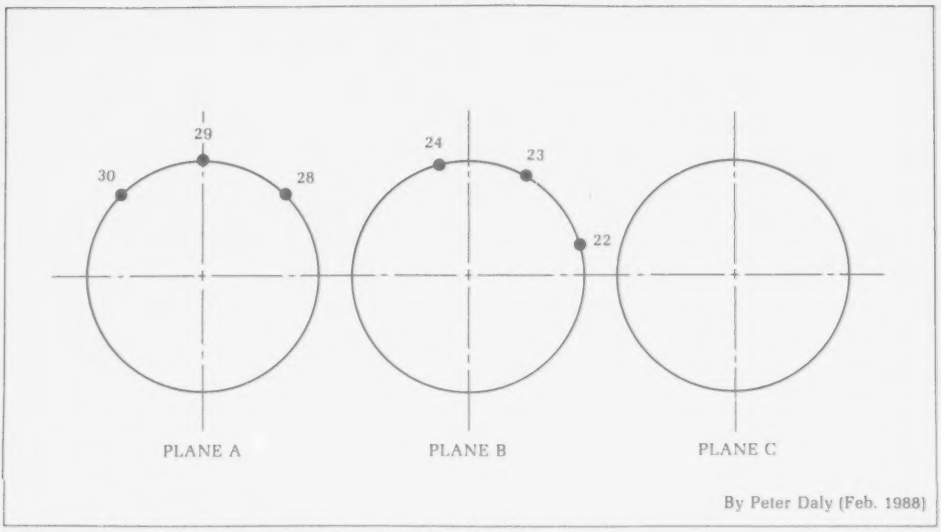
Figure 22.—Orbital Transfer During In-Plane Maneuver



29) as a convenient reference at zero phase in plane A, the current situation is shown in figure 3. Only six positions are occupied at present as shown—in slots at −45°, 0° and +45° in plane A and in slots at −15°, +30° and +75° in plane B. This provides a full four-satellite navigation facility for several hours per day on average. It should be stressed that only those satellites which currently transmit a full navigation message are included in figure 23. Occasionally older satellites transmit either plain carrier, or carrier plus code, or carrier plus code plus timing information, but not on a regular, reliable basis.

It should be noted that GLONASS has not always operated solely with the 45°-spacing within a plane now employed. In plane A, satellites have in the past been placed at 0° (Cosmos 1711), 30° (Cosmos 1519, 1520 and 1555), 45° (Cosmos 1710) as well as 75° (Cosmos 1554) phases. In plane B, spacing has always been at 45°.

Figure 23.—Current GLONASS Satellites



Communications From GLONASS

For the purposes of allowing the user to compute his own position, navigation satellites transmit details of their own positions and a time reference. In systems such as GLONASS and NAVSTAR GPS whose purpose is primarily military, the user is expected to play a passive role as any transmissions to a satellite might identify his position to an adversary. Similarly, the navigation message is protected against deliberate jamming by the use of spread-spectrum codes which increases the bandwidth occupied by the signal and hence that of the intending jammer. It should be clear however that even were the system designed to be exclusively for civil purposes, it is likely that spread-spectrum would still be used for two reasons (1) so as to minimize interference to others and (2) to provide sufficient bandwidth and hence definition of the epoch timing edge. In the following discussion the structure of the navigation message from GLONASS satellites to the user will be treated.

RADIO-FREQUENCY TRANSMISSIONS

The transmission carrier frequencies chosen for the new satellite navigation systems lie in L-band, around 1250 MHz (L_2) and 1600 (L_1). Dual-frequency navigation messages at L_1 and L_2 allow the user to correct for ionospheric propagation effects and are incorporated into both NAVSTAR and GLONASS. A high-precision military spread-spectrum code is modulated onto both carriers whereas the lower-precision civil code only appears at L_1. Spread-spectrum techniques are primarily involved to reduce the deliberate jamming of signals.

Radio-frequency carriers used by GLONASS are channelized within the bands 1240–1260 MHz and 1597–1617 MHz, the channel spacing being 7/16 or 0.4375 MHz at the lower frequencies and 9/16 or 0.5625 MHz at the higher frequencies. The carrier frequencies themselves are also multiples of channel spacing and the number of planned channels is 24. Table 33 lists the L_1 transmission frequencies and channel numbers so far employed by GLONASS satellites. Corresponding frequencies at L_2 are in the ratio 7:9.

TABLE 33.—TRANSMISSION FREQUENCIES AND CHANNEL NUMBERS (CHN)

Designator	Cosmos	GLONASS	CHN	L_1 (MHz)
1982–100A	1413	1	*	*
1982–100D	1414	2	*	*
1982–100E	1414	3	*	*
1983–84A	1490	4	3	1603.6875
1983–84B	1491	5	1	1602.5625
1983–84C	1492	6	*	*
1983–127A	1519	7	2	1603.1250
1983–127B	1520	8	24	1615.5000
1983–127C	1521	9	*	*
1984–47A	1554	10	9	1607.0625
1984–47B	1555	11	18	1612.1250
1984–47C	1556	12	*	*
1984–95A	1593	13	*	*
1984–95A	1594	14	*	*
1984–95C	1413	15	17	1611.5625
1985–37A	1650	16	7	1605.9375
1985–37B	1651	17	10	1607.6250
1985–37C	1652	18	*	*
1985–118A	1710	19	4	1604.2500
1985–118B	1711	20	19	1612.6875
1985–118C	1712	21	*	*
1986–71A	1778	22	11	1608.1875
1986–71B	1779	23	20	1613.2500
1986–71C	1780	24	22	1614.3750
1987–79A	1883	28	14	1609.8750
1987–79B	1884	29	21	1613.8125
1987–79C	1885	30	5	1604.8125

Note: All of the frequencies were measured at the University of Leeds with the exception of that of GLONASS 5, which was obtained at the Haystack Observatory in the United States.
* signifies not observed.

It should be noted that certain of the GLONASS satellites have never been observed to have achieved stable orbit. It is probably no coincidence that precisely these satellites are observed not to transmit either. Readers familiar with details of the Soviet's earlier Tsikada system [3] [4] [5] will recall that frequency space there is also

[3] Wood, C. D. and G. E. Perry. The Russian Satellite Navigation System. Philosophical Transactions of the Royal Society of London, Series A, 1980. p. 307–315.
[4] Daly, P. Cosmos Revisited. Space Communication and Broadcasting, North-Holland, 1984. p. 129–142.
[5] Daly, P. and G. E. Perry. Update of the behaviour of the Soviet Union's VHF satellite navigation system. Space Communication and Broadcasting, North-Holland, 1987. p. 379–384.

channelized with a spacing at 150 MHz of 30 kHz and all carriers multiples of the channel spacing.

INFORMATION TRANSMISSION, BANDWIDTH AND CODE RATES

As explained in a previous section, each satellite sends data at low-speed from which its own position at any reference time may be calculated. This data commonly sent at a 50-baud rate is superimposed on a pseudo-random noise (PRN) code which is, in fact, periodic and very much longer than a single data bit. The GLONASS low-precision code has a length 511 bits as compared to NAVSTAR's 1023 bits for its equivalent code. A code sequence lasts only 1 millisecond so that each data bit occupies 20 entire code sequences, the code itself or its inverse being sent depending on whether the data bit is a '0' or a '1'. In this manner, the information spectrum is spread across a wide bandwidth since bandwidth is determined by the most rapid change of state in the message. On the assumption that, in transmission, the signal will be corrupted by Gaussian noise whose power level is proportional to bandwidth, then the signal will become immersed in the noise at the receiver's terminal and recoverable only by reversing the coding operation applied at the transmitter. This implies a knowledge of the PRN codes on the part of the receiver.

The code rate can be seen from the values already given to be 511 kbits/s and 1023 kbits/s for the civil GLONASS and NAVSTAR codes respectively. Military codes are at ten times these rates and of course the sequence lengths are very much longer. In order to transmit the encoded data, a binary phase-shift keyed (BPSK) modulation technique is employed, the first nulls in the transmitted spectrum at $\pm$ the bit rate. Hence bandwidths for the GLONASS transmission can be taken at 1 MHz and 10 MHz for the civil and military codes respectively. These figures compare with 2 MHz and 20 MHz for NAVSTAR's equivalent bandwidths.

At the L_2 frequency only the high-rate code is carried, but at L_1 both codes are transmitted on the same carrier, one in phase and the other in quadrature. This results in a signal spectrum which superimposes the two individual spectra whose bandwidths differ by a factor of ten. Since both transmissions carry the same power, a spectrum analyzer will display the narrower-band code at ten times the strength of the wide-band code.

ACCURACY OF THE TIME INTERVAL MEASUREMENT

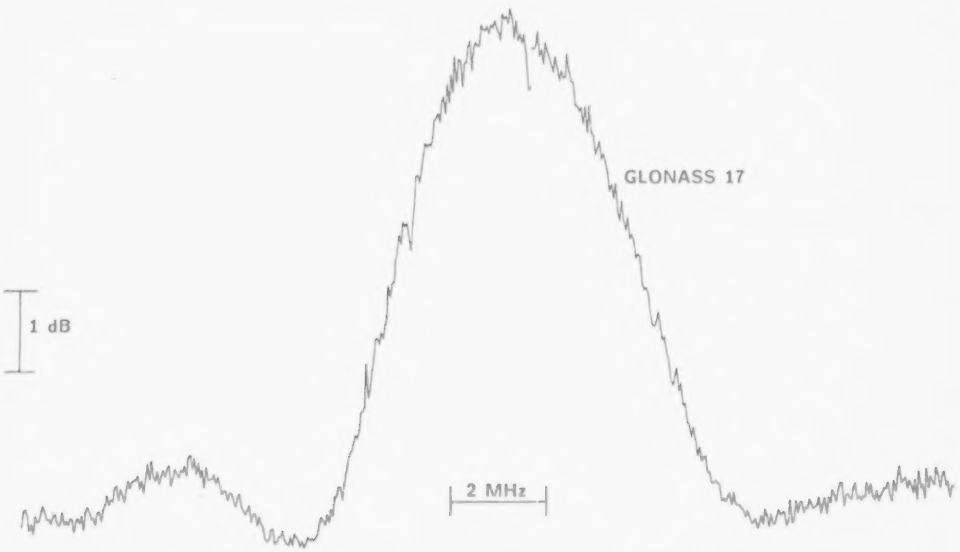
In determining the accuracy with which time or its equivalent pseudo-range can be measured, it is important to remember that three different quantities are available (1) code phase (2) integrated code frequency or (3) carrier phases proceeding to higher and higher accuracies at each stage. In crude terms one can measure code phase meaning the time interval between local and transmitted code epochs to an accuracy limited by the code frequency, the signal/noise ratio and the bandwidth of the measurement. Ultimately, if all satellite onboard frequency sources are locked to the same frequency standard, the accuracy available is limited by the stability of that standard. In the case where onboard standards are synchronized atomic clocks, range and hence position can be estab-

lished to a fraction of a wavelength at the carrier frequency. At L-band frequencies of 1.6 GHz, the free-space wavelength is around 190 mm.

FEATURES OF THE GLONASS SIGNAL SPECTRUM

The classical BPSK spectrum consists of a sinc^2 (sinc x = sin x/x) shape centered on the carrier frequency with nulls at multiples of the bit rate. Usually, the signal is filtered before transmission to limit the transmission bandwidth to only the first two nulls nearest the carrier. Given a receiving antenna of sufficient gain to extract the signal from the surrounding noise, we would therefore expect to observe a spectrum at the L_2 frequencies around 1.2 GHz where only the wideband code is present such as the one referring to GLONASS 17 shown in figure 24.

Figure 24.—GLONASS Frequency Spectrum (GLONASS 17)

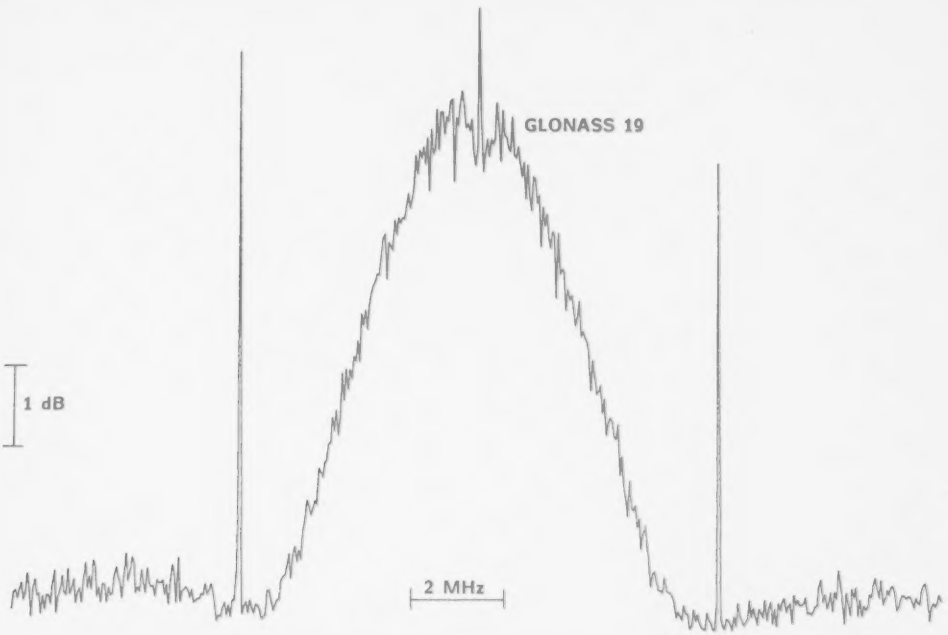


GLONASS 17 signal spectrum at L_2 frequency Vertical scale 1*d*B/div; Horizontal scale 2 MHz/div, by Peter Daly.

Some of the GLONASS satellites have additional spectral lines precisely at the spectral nulls ± the code rate expressed in terms of bandwidth. An example of such a spectrum is shown in figure 25 for GLONASS 19. The appearance of these spectral lines is indeed puzzling especially as they appear on some GLONASS satellites and not on others.

Occasionally two GLONASS satellites occupying the same orbital slot transmit simultaneously, each of course at its own carrier frequency. An interesting example of this is shown in figure 26; the spectrum was taken in late April 1986 as GLONASS space vehicles 7 and 8 passed through the main beam of the 3 meter antenna almost simultaneously. Additional spectral lines at the code nulls are seen on both spacecraft; in addition, GLONASS 8 displays a residual carrier component.

Figure 25.—GLONASS Frequency Spectrum (GLONASS 19)

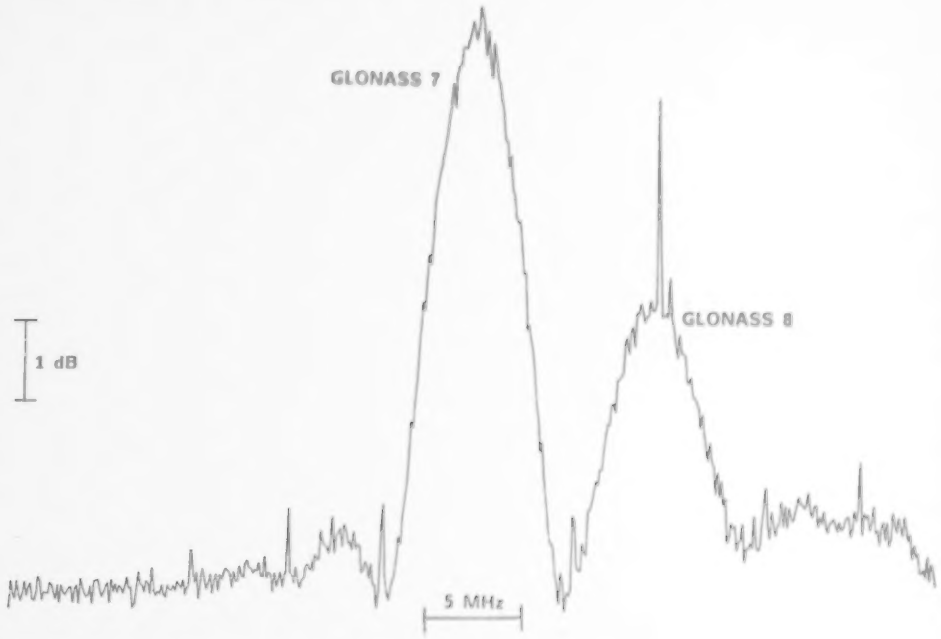


GLONASS 19 signal spectrum at L_2 frequency Vertical scale 1*d*B/div; Horizontal scale 2 MHz/div, by Peter Daly.

Two plausible theories can be advanced to explain the appearance of spectral lines at code nulls in received spectra. The first of these theories postulates that the lines are present by accident as a result of poor implementation of the carrier modulation circuitry which fails to balance out these particular sidebands. This argument is supported by the appearance of the lines on certain satellites and not on others. The second argument proposes that the lines are there quite deliberately in order to provide the instantaneous velocity information on the satellite in question. On the supposition that the lines are present due to additional modulation—perhaps frequency modulation—of a subcarrier frequency at the code rate and synchronized to all satellites, then reception of the subcarrier from two satellites followed by phase comparison would provide an instantaneous measure of range difference from the two satellites. This range difference could then be used to resolve ambiguities in the pseudo-range measurements to individual satellites.

The most recent satellites on which spectral lines have been observed are GLONASS 19 and 20. No lines are observable on any of the last six satellites successfully launched (GLONASS 22–24 and 28–30). Since the GLONASS system has been the subject of intense experimentation and change since the first launch, neither of the two above theories can be rejected at this stage.

Figure 26.—GLONASS Frequency Spectrum (GLONASS 7 and 8)



GLONASS 7 and 8 signal spectra at L_2 frequency Vertical scale 1*d*B/div; Horizontal scale 2 MHz/div, by Peter Daly.

INTERPRETATION OF THE DATA MESSAGE

The message data transmitted by GLONASS satellites arrives at the rate of 50 baud together with additional information in the form of preambles and parity bits. As is common with such transmissions, the data is formatted into frames, sub-frames and words of data. A frame whose duration is 150 seconds is sub-divided into five sub-frames. Sub-frames are divided into 15 lines, each of which consists of a preamble followed by a line number, data parameter and parity bits. The data in each sub-frame divides into two sections, the first relating to the coordinates and clock parameters of the transmitting satellite and the second to almanacs for all other satellites currently in the system (cf. the Tsikada system). Various flags occur in the message relating to validity of specific data, status and health of particular satellites. Parts of the data message are not understood or only partially understood, for example, the luni-solar correction term in the almanacs.

SATELLITE EPHEMERIDES

Readers familiar with the format used by the Soviet Union in transmitting Tsikada ephemerides will find remarkable similarities to the GLONASS ephemerides. Both systems encode the satellite's instantaneous position and velocity at fixed time intervals in an Earth-centered, Earth-fixed (ECEF) rectangular coordinate system.

Positions and velocities at intermediate times are intended to be calculated using interpolation procedures.

In addition to positional data at reference times, GLONASS also transmits in the ephemeris two parameters relating to the onboard clocks, the first a time correction and the second a frequency correction and an age-of-ephemeris-data (AODE) parameter. The first time offset refers to the instantaneous time difference between space vehicle time and GLONASS system time. The second parameter gives the rate of change of space vehicle time offset. Use of both parameters allows the user to establish individual space vehicle time offsets at any required instant of observation.

SATELLITE ALMANACS

There is a greater similarity between NAVSTAR and GLONASS in the transmission of almanacs. Both systems transmit the basic elements of an osculating Kepler ellipse as shown in table 34.

TABLE 34.—NAVSTAR AND GLONASS ALMANACS COMPARED

Parameter	NAVSTAR	GLONASS
0	week of validity	day of validity
1	identifier	channel number
2	eccentricity	eccentricity
3	inclination	inclination
4	time of almanac	equator crossing time
5	health	validity of almanac
6	right ascension (RA)	equator crossing longitude
7	rate of change of RA	—
8	root of semi-major axis	orbital period
9	argument of perigee	argument of perigee
10	mean anomaly	—
11	—	luni-solar term
12	time offset	time offset
13	frequency offset	—

In terms of using almanacs to predict satellite position from the reduced Kepler orbit, the two sets of data are quite similar as one would expect. Where differences occur (parameter 8), the terms are seen to be equivalent.

Formally one would expect the primary purpose of almanac data to be to allow the user to predict in fairly crude terms which satellites are above his local horizon at a given time and whether their geometry is favorable for navigation. This end would be achieved by almanacs giving a position of each satellite to within 100–200 meters and is the case with the NAVSTAR almanac. However, the inclusion in the GLONASS almanac of a luni-solar correction term implies a position error perhaps an order of magnitude better than a NAVSTAR almanac. The luni-solar term remains substantially constant for satellites with the same Right Ascension. The purpose of the inclusion of such a term might possibly be in order to aid satellite acquisition following a "cold start" but clearly other interpretations are possible.

Almanacs are valid for several days in the case of NAVSTAR; they are usually, but not always, changed every day in GLONASS at local midnight. It is interesting to observe that the GLONASS

almanacs differ from the earlier Tsikada almanacs in one major respect—the earlier almanacs were based on an equinoctial Kepler set where the eccentricity and argument of perigee are transmitted as h = e sinw and l = e cos w. The equinoctial set of elements is suitable for orbits of small eccentricity since it leads to equations with no singularities when e tends to zero.

Current Operational Status

As of the end of 1987 the GLONASS satellite system is clearly still in a pre-operational phase. Only two of the three orbital planes are occupied and even these only partially. As we have observed over many years with Tsikada, Soviet spacecraft are replaced at a rate very much higher than their U.S. equivalents. The question of how many satellites are operational at any given time is a difficult one to answer since the situation is complicated by several factors. The problem arises because satellites may not remain in a particular state for any length of time. Over a period of weeks a particular satellite may (1) not transmit at all, (2) transmit plain carrier, (3) transmit carrier plus code but no data, (4) transmit carrier plus code and limited data or, (5) transmit a full message. With this reservation in mind, table 35 shows the current status of the GLONASS satellite navigation system as of the end of 1987. Six satellites are operational as compared with six/seven satellites for NAVSTAR GPS.

TABLE 35.—GLONASS SYSTEM AT THE END OF 1987

International	Cosmos	GLONASS	Carrier	Code	Data
1983-84A	1490	4	YES	NO	NO
1983-127B	1520	8	YES	YES	NO
1984-47A	1554	10	YES	YES	NO
1985-37B	1651	17	YES	YES	TIME ONLY
1985-118A	1710	19	YES	YES	TIME ONLY
1986-71A	1778	22	YES	YES	YES
1986-71B	1779	23	YES	YES	YES
1986-71C	1780	24	YES	YES	YES
1987-79A	1883	28	YES	YES	YES
1987-79B	1884	29	YES	YES	YES
1987-79C	1885	30	YES	YES	YES

CONCLUSIONS

Features of the orbital behavior of the GLONASS satellite navigation system have been discussed which lead to a better understanding of the aims of the program. GLONASS is designed with three orbital planes separated by 120° with eight satellites equally-spaced in each plane. Phase differences of ± 30° between satellites in the three planes ensures a repeatability in ground-track for all 24 satellites in the system. Any observer on the surface of the Earth who can point a high-gain antenna at any GLONASS satellite will note that within the following eight days each of the remaining satellites will automatically pass through the antenna beam. This is perhaps more of advantage to the ground controllers than the navigator who would, of course, in practice use an anten-

na with hemispherical coverage so as to be able to receive four satellites simultaneously.

It would be wrong to surmise that once a GLONASS satellite's transmissions cease for a time, that the satellite is dead. Previous experience with Tsikada and with the new system shows that certain satellites have resumed service even after a long absence. Currently, GLONASS has around six satellites in full operation (this figure does not remain constant over longer periods), in comparison with NAVSTAR GPS which has six or seven satellites fully functional. During the next three to four years, it is expected that both systems will become fully operational.

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CHAPTER 4—SOVIET MILITARY SPACE ACTIVITIES

As described in the historical summary provided in chapter 1, the Soviet Union has developed a broad range of military space programs for photographic, radar, and electronic surveillance; early warning of missile and space launches; strategic, tactical and theater, and covert store-dump communications; navigation, and anti-satellite weapons.

Soviet use of space for military purposes during the period 1984 through 1987 continued along the well established lines reported in previous editions of this report. Few new developments appeared. Some programs which had been in the research and development phase attained full operational capability. Others saw the introduction of new generation spacecraft and the phasing out of the older versions. Replacement of failed or aging satellites was routine with some in the latter category being retired to a stand-by mode as in-orbit spares. Resurrection of such satellites to fill-in for later satellites which had incurred point failure were noted from time to time.

Particular noteworthy instances are reported in this chapter along with observable trends. In most cases, tables have been compiled for the different military programs within the Cosmos series of satellites and, where appropriate, these have been sub-divided by orbital inclination and/or altitude regime to reveal further sub-sets within each program. Tables have also been compiled to summarize the replacement sequences which have maintained well-defined constellations of satellites.

From time to time a number of fragments appear in an orbit formerly occupied by a single object. In the case of a discarded rocket stage the fragmentation may be due to the ignition of remnants of hypergolic propellants which, for some reason or other, come into contact. In rare instances the fragmentation may be due to a catastrophic propulsion failure while the stage is firing.

The Cosmos program provides many examples of fragmentations which appear to have been deliberately initiated to destroy sensitive military payloads which have either completed their missions or malfunctioned in some respect.

The antisatellite (ASAT) tests have produced many fragments when the interceptors have been destroyed following the completion of their test. These are indicated by the prefix of a letter "E" added to the Cosmos number in table 5 (in Chapter 1).

Some EORSATS are seen to fragment after the end of the active phase of their mission as determined by the cessation of station-keeping maneuvers. These are indicated by an asterisk following the date in the "Down" column of table 44. Such fragmentations are believed to be deliberate.

There have been occasions when, following an unsuccessful attempt to recover the payload of a photo-reconnaissance Cosmos, the

payload has been deliberately exploded by ground-command. On these occasions, shortwave telemetry has continued to be monitored by the Kettering Groups following the fragmentation, implying that the instrument module remains intact and that the recoverable capsule only is fragmented.

A comprehensive analysis of all on-orbit fragmentations through October 4, 1987 was prepared by Teledyne Brown Engineering for Lockheed EMSCO Inc.[1]

Observation Missions

PHOTOGRAPHIC RECONNAISSANCE

Third Generation, High Resolution Missions

Such missions have declined in importance over the period under consideration due to the increased use of fourth and fifth generation spacecraft flying missions of increased duration. They are still employed in crisis situations or when additional imagery is urgently required.

Table 36 lists the Cosmos satellite launches in this category from 1984 through 1987. It will be noted that there has been only one mission at the 62.8° inclination and that was back in 1984. It may be that this was not purely for military photo-reconnaissance but could have been a precursor of the materials processing flights, which were acknowledged for Cosmos 1645, Cosmos 1744 and Cosmos 1841 in successive years from 1985 through 1987, culminating with Foton 1 in 1988. However, those flights had significantly greater eccentricities and higher orbital periods.[2]

The choice of two distinctly different orbital inclinations of 70.0° and 70.4° for missions launched from Tyuratam has yet to be satisfactorily explained, unless it is simply the result of the use of two widely separated A–2 launch pads at the cosmodrome.

The majority of missions in this category are launched into 72.9° inclinations from Plesetsk. Nearly half of these have been recovered before the 14th day, lending weight to the hypothesis of some degree of urgency being associated with many of these missions.

The two flights at 82.3° the inclination now used almost solely for the film-return remote sensing missions described in the previous chapter, had short durations only.

Third Generation, High Perigee Missions

These missions are believed to be used for area surveillance on a search-and-find basis at medium resolution to locate new developments or targets for subsequent investigation by higher resolution systems. Toward the end of the first 24 hours in orbit the engine is fired at apogee to raise the orbital period to 92.2 minutes for Tyuratam missions at 70.0° or 70.4° or 92.3 min for Plesetsk missions at 72.9° the difference in period resulting from the desire to obtain complete coverage during the two-week mission.

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[1] Johnson, N. L. and D. J. Nauer. History of On-Orbit Satellite Fragmentations. 3rd ed., Teledyne Brown Engineering, Colorado Springs, CO., 1987.

[2] See table 30 in chapter 3.

TABLE 36.—HIGH RESOLUTION, THIRD GENERATION, COSMOS PHOTOGRAPHIC RECONNAISSANCE SATELLITES: 1984–1987

Cosmos number and designator		Launch date and site		Apogee	Perigee	Inclination	Orbital period	Life
1580	84–70A	6/29/84	PL	271	228	62.8	89.5	14
1728	86–09A	1/28/86	TT	273	225	70.0	89.5	14
1787	86–81A	10/22/86	TT	281	230	70.0	89.6	13
1668	85–60A	7/15/85	TT	281	230	70.4	89.6	14
1696	85–95A	10/16/85	TT	281	230	70.4	89.6	14F
1747	86–41A	5/29/86	TT	256	211	70.4	89.2	14
1895	87–92A	11/11/87	TT	288	228	70.4	89.7	15
1899	87–99A	12/7/87	TT	302	208	70.4	89.6	14
1905	87–107A	12/21/87	TT	281	228	70.4	89.6	14
1551	84–44A	5/11/84	PL	258	212	72.9	89.2	12
1573	84–61A	6/19/84	PL	312	229	72.9	89.9	9
1592	84–94A	9/4/84	PL	295	233	72.9	89.8	14
1632	85–19A	3/1/85	PL	267	209	72.9	89.3	14
1664	85–54A	6/26/85	PL	379	224	72.8	90.6	9
1665	85–57A	7/3/85	PL	292	224	72.8	89.7	14
1671	85–65A	8/2/85	PL	258	229	72.9	89.4	14F
1715	86–01A	1/8/86	PL	283	227	72.8	89.6	14
1730	86–12A	2/4/86	PL	283	227	72.9	89.6	9
1790	86–85A	11/4/86	PL	282	228	72.9	89.6	14
1819	87–14A	2/7/87	PL	256	209	72.8	89.2	11
1822	87–19A	2/19/87	PL	287	228	72.9	89.7	14
1872	87–69A	8/19/87	PL	385	247	72.9	90.9	11
1874	87–72A	9/3/87	PL	288	226	72.9	89.7	14
1648	85–32A	4/25/85	PL	327	229	82.3	90.1	11
1837	87–35A	4/22/87	PL	247	226	82.2	89.3	6

Notes:
1. All satellites were launched by the A–2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. The letter F at the end of an entry signifies that a TF recovery beacon was observed by the Kettering Group at the end of the mission.
5. Table prepared for the Congressional Research Service by G. E. Perry.

As in the case of the high resolution missions discussed above, Plesetsk accounts for the majority of these missions and the Tyuratam missions are divided between two inclinations differing by only 0.4°

Two missions from 1984 merit special mention. Cosmos 1587 and Cosmos 1613 remained in the low initial orbit for 12 days, making no maneuvers. Apart from signals received by Peter Wakelin from Cosmos 1587 on its day of launch, the Kettering Group did not observe any further shortwave transmissions during those 12-day periods. On the thirteenth day of each mission both satellites maneuvered into the high-perigee orbit which provided complete global coverage within 13 days, or 210 orbits. Both satellites were recovered after 25 days, having transmitted normally in the shortwave band through the second phase of their missions. Both satellites were launched close to 1400 GMT, much later than usual for a normal high-perigee mission, ensuring normal lighting conditions over the second phase when passes were coming earlier in the day.

This particular flight profile has not reappeared and if it was designed to test the possibility of in-orbit storage of reconnaissance satellites in the short-term then presumably the need has not arisen or else the concept has been abandoned.

Table 37 lists the Cosmos satellite launches in this category from 1984 through 1987.

TABLE 37.—HIGH PERIGEE, THIRD GENERATION, COSMOS PHOTOGRAPHIC RECONNAISSANCE SATELLITES: 1984–1987

Cosmos number and designator		Launch date and site		Apogee	Perigee	Inclination	Orbital period	Life
1587	84–82A	8/6/84	PL	368	197	72.9	90.2	25
1613	84–121A	11/29/84	PL	356	197	72.8	90.0	25
1571	84–58A	6/11/84	TT	415	348	70.0	92.2	15
1600	84–103A	9/27/84	TT	416	349	70.0	92.2	14
1623	85–05A	1/16/85	TT	415	349	70.0	92.2	14
1760	86–48A	6/19/86	TT	415	350	70.0	92.2	14F
1804	86–95A	12/4/86	TT	415	347	70.0	92.2	14
1889	87–85A	10/9/87	TT	415	348	70.0	92.2	14
1533	84–06A	1/26/84	TT	415	346	70.4	92.2	14
1542	84–25A	3/7/84	TT	414	348	70.4	92.2	14F
1644	85–27A	4/3/85	TT	415	349	70.4	92.2	14
1775	86–66A	9/3/86	TT	414	348	70.4	92.2	14
1781	86–72A	9/17/86	TT	413	349	70.4	92.2	14
1843	87–39A	5/5/87	TT	415	347	70.4	92.2	14F
1845	87–42A	5/13/87	TT	415	348	70.4	92.2	14
1530	84–02A	1/11/84	PL	416	356	72.8	92.3	14
1545	84–30A	3/21/84	PL	415	356	72.8	92.3	15
1549	84–40A	4/19/84	PL	415	356	72.9	92.3	14F
1568	84–54A	6/1/84	PL	414	357	72.8	92.3	13
1583	84–75A	7/24/84	PL	415	357	72.9	92.3	15
1609	84–117A	11/14/84	PL	414	356	72.9	92.3	14
1628	85–12A	2/6/85	PL	415	355	72.9	92.3	14
1649	85–36A	5/15/85	PL	415	356	72.9	92.3	14
1659	85–46A	6/13/85	PL	415	357	72.9	92.3	14
1683	85–83A	9/19/85	PL	414	356	72.9	92.3	15
1685	85–85A	9/26/85	PL	416	356	72.9	92.3	14
1702	85–106A	11/13/85	PL	414	356	72.9	92.3	14F
1705	85–111A	12/3/85	PL	415	356	72.9	92.3	14
1740	86–29A	4/15/86	PL	416	355	72.9	92.3	13F
1742	86–33A	5/14/86	PL	418	353	72.9	92.3	14F
1765	86–54A	7/24/86	PL	415	356	72.9	92.3	14F
1772	86–63A	8/21/86	PL	415	356	72.9	92.3	13
1813	87–04A	1/15/87	PL	416	356	72.8	92.3	dis
1826	87–25A	3/11/87	PL	414	356	72.9	92.3	14
1848	87–47A	5/28/87	PL	414	356	72.9	92.3	14F
1863	87–56A	7/4/87	PL	416	357	72.9	92.3	14
1907	87–110A	12/29/87	PL	415	356	72.8	92.3	14

Notes:
1. All satellites were launched by the A–2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. The letter F at the end of an entry signifies that a TF recovery beacon was observed by the Kettering Group at the end of the mission.
5. Table prepared for the Congressional Research Service by G. E. Perry.

Fourth Generation, High Resolution Missions

Throughout the period under consideration the trend toward increased use of satellites with mission durations of up to two months at the expense of the third generation two-week missions has continued and only on rare occasions have such satellites not been in orbit. Instances of such periods exceeding one week occurred from June 22 through August 16, 1985, following the explosion of Cosmos 1654 after only 30 days, October 21 through Novem-

ber 12, 1986, February 13 through February 26, 1987, and June 26 through September 16, 1987, following the explosion of Cosmos 1866 after only 17 days.

The latter part of one mission usually overlaps the early phase of a later mission and on two occasions a satellite was launched on the same day as another mission was terminated.

Two inclinations only are employed in these missions—64.8° from Tyuratam and 67.2° from Plesetsk. Perigees are maintained close to 170 km to obtain high resolution imagery with orbital maneuvers controlled by adjustment of apogee heights in the region of 340 km.

Consideration of the apogee/perigee height criteria led to the reassignment of Cosmos 1654 from fifth to fourth generation. Kettering Group failure to intercept radio transmissions on 240 MHz from Cosmos 1654 during the month prior to its explosion had suggested that it might belong to the former class.

It is probable that film capsules are returned at intervals during these missions. Morse code TV recovery beacons were observed from such capsules when this class of satellite was first introduced but have not been observed recently, probably due to failure to monitor at the appropriate times. Digital image return is also a distinct possibility.

Until the end of 1987, the fate of this class of satellite at the end of a mission was still subject to debate. Extrapolation of orbital element sets for fragments which appear in orbit at the end of a mission to determine at what time they separated from the parent spacecraft does not provide conclusive evidence in favor of either recovery or controlled de-orbit over the Pacific Ocean. Ground tracks at the times of separation are suitable for either scenario. Due to the lengthy duration of these missions, times of such events occur during hours of darkness in Western Europe which are not conducive to Kettering Group observation of recovery beacons, should they exist.However, a chance observation of a glowing cloud in the night sky over Zambia, has provided the first piece of conclusive evidence in favor of payload recovery. D. MacIntyre and three colleagues reported their observation at 2003 GMT on July 4, 1988, from 15° 02'S, 26° 00'E in a letter to Russell Eberst of the Royal Scottish Observatory, Edinburgh, who realized that it could have been the firing in orbit of a low rocket and suggested that it could have been the retrofire of Cosmos 1942,[3] which was known to have disappeared from orbit on July 4.9.[4] This was quickly confirmed by computing that the ground track of Cosmos 1942 on that date passed over Zambia at the time of the observation and continued northward across Uganda, Baghdad in Iraq, Baku on the Caspian Sea, and on into Kazakhstan to the south of the Urals. From this it could be concluded that the payload was recovered rather than deorbited and the recovery time was refined to July 4.85.

Table 38 lists the Cosmos satellite launches in this category from 1984 through 1987.

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[3] Eberst, R. J. Private communication.
[4] The RAE Table of Earth Satellites, Up-date, July 11, 1988, p. 949b.

TABLE 38.—FOURTH GENERATION COSMOS PHOTOGRAPHIC RECONNAISSANCE SATELLITES: 1984–1987

Cosmos number and designator		Launch date and site		Apogee	Perigee	Inclination	Orbital period	Life
1585	84–77A	7/31/84	TT	302	174	64.7	89.3	59
1611	84–119A	11/21/84	TT	351	173	64.7	89.8	51
1616	85–02A	1/9/85	TT	368	189	64.9	90.1	54
1630	85–17A	2/27/85	TT	336	175	64.9	89.6	55
1654	85–39A	5/23/85	TT	343	172	64.9	89.7	dis
1679	85–78A	8/29/85	TT	343	173	64.9	89.7	50
1739	86–28A	4/9/86	TT	329	173	64.9	89.5	59
1756	86–43A	6/6/86	TT	344	173	64.9	89.7	59
1764	86–53A	7/17/86	TT	346	174	64.9	89.7	56
1773	86–64A	8/27/86	TT	345	173	64.9	89.7	55
1792	86–87A	11/13/86	TT	336	173	64.9	89.6	53
1811	87–02A	1/9/87	TT	344	172	64.8	89.7	35
1835	87–32A	4/9/87	TT	340	171	64.8	89.6	56
1901	87–102A	12/14/87	TT	345	173	64.9	89.7	51
1532	84–04A	1/13/84	PL	359	166	67.1	89.8	44
1539	84–20A	2/28/84	PL	374	182	67.2	90.1	41
1548	84–36A	4/10/84	PL	333	167	67.1	89.5	45
1558	84–50A	5/25/84	PL	341	172	67.2	89.6	44
1576	84–66A	6/26/84	PL	351	170	67.1	89.7	59
1599	84–102A	9/25/84	PL	319	179	67.1	89.5	56
1647	85–31A	4/19/85	PL	323	169	67.1	89.4	53
1676	85–72A	8/16/85	PL	347	166	67.2	89.6	59
1699	85–101A	10/25/85	PL	339	167	67.1	89.6	59
1706	85–112A	12/11/85	PL	334	167	67.2	89.5	60
1724	86–04A	1/15/86	PL	334	168	67.2	89.5	59
1734	86–20A	2/26/86	PL	348	163	67.1	89.6	59
1807	86–99A	12/16/86	PL	338	166	67.1	89.6	38
1824	87–21A	2/26/87	PL	345	167	67.2	89.6	55
1847	87–46A	5/26/87	PL	346	162	67.2	89.6	57
1866	87–59A	7/9/87	PL	358	166	67.2	89.8	dis
1886	87–81A	9/17/87	PL	356	167	67.1	89.8	46
1893	87–89A	10/22/87	PL	340	167	67.2	89.6	55

Notes:
1. All satellites were launched by the A–2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Cosmos 1654 and Cosmos 1866 were deliberately exploded by ground command after 30 days and 17 days respectively.
5. Table prepared for the Congressional Research Service by G. E. Perry.

A Special Sub-Set

Following the launch of Cosmos 1944, to which representatives of the Western media were invited, Nicholas Johnson of Teledyne Brown Engineering pointed out a sub-set of satellites within those considered to be fourth generation.[5] He drew attention to the fact that these particular satellites, which were all launched from Tyuratam, had a more tightly controlled altitude regime than fourth or fifth generation satellites. Cosmos 1246, Cosmos 1370 and Cosmos 1516 in 1981, 1982 and 1983 respectively, and Cosmos 1608, with the unique 70.0° inclination in 1984, had perigees close to 197 km, but subsequent satellites had perigees some 10 km higher. Radar cross-sections were compatible with Soyuz-type spacecraft rather than Vostok-type and no debris was detected following de-orbit/re-

[5] Johnson, N. L. Private communication.

covery. The mission of Cosmos 1944 was loosely described as topographical and these satellites may prove to be the successors of the earlier special sub-set of third generation satellites believed to have geodetic roles.

Table 39 lists the Cosmos satellite launches in Johnson's special sub-set from 1984 through 1987.

TABLE 39.—SPECIAL SUB-SET OF FOURTH GENERATION COSMOS PHOTOGRAPHIC RECONNAISSANCE SATELLITES: 1984–1987

Cosmos number and designator		Launch date and site		Apogee	Perigee	Inclination	Orbital period	Life
1673	85–68A	8/8/85	TT	273	198	64.8	89.2	42
1784	86–77A	10/6/86	TT	275	216	64.8	89.4	36
1865	87–58A	7/8/87	TT	268	208	64.8	89.3	37
1896	87–93A	11/14/87	TT	267	209	64.8	89.3	41
1608	84–116A	11/14/84	TT	251	197	70.0	89.0	33

Notes:
1. All satellites were launched by the A–2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

Fifth Generation Long-Duration Missions

The Kettering Group, despite repeated attempts, has failed to intercept any radio transmissions from the satellites which fly missions with durations of six months or more before being de-orbited. It must be presumed that the digital image return from these satellites is at gigahertz frequencies.

Single missions in the years 1984 and 1985 spanned the months in the middle of those years. From the launch of Cosmos 1731 on February 7, 1986, a fifth generation satellite was in orbit at all times through the end of 1987. For 58 days in 1986 and from April 16 through December 2, 1987, two fifth generation satellites were in orbit simultaneously. During this latter period, Cosmos 1881 was launched on the same day that Cosmos 1810 was recovered after a record-breaking 259-day mission. It was noticeable that during the period when Cosmos 1836 and Cosmos 1881 were in orbit together, maneuvers to counteract orbital decay by raising the apogees occurred at around the same time. The orbital plane separation of these two satellites was close to 90° as were those for Cosmos 1770/Cosmos 1810 and Cosmos 1810/1836. This was achieved by timing the launch of Cosmos 1881 to ensure that it was placed precisely into the same plane as Cosmos 1810, which it was replacing. The plane separation of Cosmos 1731/Cosmos 1770 in 1986 was approximately 160°

Cosmos 1543, launched on October 10, 1984, and Cosmos 1713, launched on December 27, 1985, do not fall into any of the categories described so far. Both missions lasted for 26 days and originated from Plesetsk at 62.8° inclination. Apogee and perigee heights close to 385 km and 216 km closely matched those of Cosmos 1645 and Cosmos 1841, which were announced as materials processing missions and, in view of the 30-day mission durations offered com-

mercially for Foton (see chapter X), it is quite possible that these were missions related to that program.

Table 40 lists the Cosmos satellite launches in this category from 1984 through 1987.

TABLE 40.—FIFTH GENERATION COSMOS PHOTOGRAPHIC RECONNAISSANCE SATELLITES: 1984–1987

Cosmos number and designator		Launch date and site		Apogee	Perigee	Inclination	Orbital period	Life
1552	84–45A	5/14/84	TT	322	182	64.9	89.5	173
1643	85–26A	3/25/85	TT	294	223	64.8	89.7	207
1731	86–13A	2/7/86	TT	269	183	64.8	89.0	238
1770	86–60A	8/6/86	TT	281	238	64.8	89.7	180
1810	86–102A	12/26/86	TT	279	182	64.8	89.1	259
1836	87–33A	4/16/87	TT	293	241	64.8	89.9	230
1881	87–76A	9/11/87	TT	276	231	64.8	89.6	201

Notes:
1. All satellites were launched by the A–2.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to recovery in integer days.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

Degree of Photographic Coverage

Table 41 summarizes the degree of photographic reconnaissance coverage obtained by the Soviet's on a day-to-day basis from 1984–1987. Two sets of data are provided. The second set, in parentheses, includes the possible dual role recoverable photographic remote sensing satellites, described in chapter 3 and listed in table 20.

It will be seen that with the exception of three days in 1984, or one day only if the remote sensing satellites are included, the Soviet Union has had a year-round photographic reconnaissance capability. With the exception of 1985, three or more photographic reconnaissance satellites were in orbit simultaneously for the greater part of each year and in 1987, even without the inclusion of the remote sensing satellites, six satellites were in orbit simultaneously on nine days.

The numbers in bold type attempt to account for the coverage provided by having more than one satellite in orbit at a time by computing mission-days as the product of the multiplication of the number of days by the number of satellites in orbit simultaneously on those days.

TABLE 41.—COSMOS PHOTOGRAPHIC RECONNAISSANCE SATELLITES: 1984–1987

Year	Number of days with a given number of satellites in orbit							Total
	0	1	2	3	4	5	6	
1984	3	65	93	158	45	2	—	366
	(1)	(55)	(80)	(145)	(45)	(30)	(10)	(366)
	—	**65**	**186**	**474**	**180**	**10**	**—**	**915**
	(—)	**(55)**	**(160)**	**(435)**	**(180)**	**(150)**	**(60)**	**(1040)**
1985	—	72	146	99	40	8	—	365
	(—)	(68)	(140)	(70)	(41)	(40)	(6)	(365)
	—	**72**	**292**	**297**	**160**	**40**	**—**	**861**
	(—)	**(68)**	**(280)**	**(210)**	**(164)**	**(200)**	**(36)**	**(958)**
1986	—	—	110	168	70	17	—	365
	(—)	(—)	(94)	(134)	(116)	(21)	(—)	(365)
	—	**—**	**220**	**504**	**280**	**85**	**—**	**1089**
	(—)	**(—)**	**(188)**	**(402)**	**(464)**	**(105)**	**(—)**	**(1159)**
1987	—	1	47	160	106	42	9	365
	(—)	(1)	(47)	(136)	(121)	(43)	(17)	(365)
	—	**1**	**94**	**480**	**424**	**210**	**54**	**1263**
	(—)	**(1)**	**(94)**	**(408)**	**(484)**	**(215)**	**(102)**	**(1304)**

Notes:
1. Numbers in parentheses are totals including the recoverable photographic remote sensing satellites.
2. Bold numbers are mission-day totals as the products of multiplication of the number of days by the number of satellites in orbit on those days.
3. Lives of satellites are computed as integer numbers of days by subtracting the launch date from the date of recovery, de-orbit, or fragmentation.
4. Table prepared for the Congressional Research Service by G. E. Perry.

Identification of Possible Targets

As has already been mentioned in chapter 1, attempting to identify the photographic target(s) of a particular mission is a hazardous pastime, particularly with prolonged crisis periods such as the conflict in the Persian Gulf and the Soviet occupation of Afghanistan. The annual Soviet Year in Space reports produced by Nicholas Johnson does attempt such identification and table 42 summarizes the findings of those reports.

OBSERVATIONS BY COSMONAUTS

As has been stated in the historical summary in chapter 1 of this part of the report and described in some detail in part 1,[6] cosmonauts in Soyuz spacecraft and onboard the Salyut and Mir space stations make routine photographic observations of areas of particular interest using cameras such as the KATE–140 and MKF–6. Although no specific instances have been reported during 1984–1987, it would be surprising if the cosmonauts (the majority of whom are, or have been at some time, active military personnel) did not, on occasion take photographs and make visual observations at the request of the military command.

RORSATS

The Soviet's acknowledged the existence of its radar ocean reconnaissance satellite (RORSAT) program at the 1985 Pugwash Conference in Björkliden, Sweden.[7] Claiming that "the presence of U.S.

[6] *Soviet Space Programs: 1981–87,* Part 1, p. 46–49, 90.
[7] Arbatov, A. G. Prevention of the Militarization of Space. Nuclear Strategy and World Security, Macmillan, London, 1985. p. 99–102.

TABLE 42.—POSSIBLE TARGETS OF COSMOS PHOTOGRAPHIC RECONNAISSANCE SATELLITES: 1984–1987

Cosmos number	Period of observation	Target area	Type	Page number	Fig and page
1548	4/20–4/23/84	Gulf War	Third	14–15	11,14
	5/10/–5/15/84				12,14
1599	10/29–11/1/84	Chad	Fourth	15–16	13,15
	11/14–11/18/84				
1611	12/19–12/22/84	Somalia (and El Salvador).	Fourth	16–17	14,16
	1/6–1/8/85	Gulf War		15	—
1616	1/16–1/20/85	Afghanistan	Fourth	16	15,16
1630	3/30–4/2/85	Gulf War	Fourth	16–17	16,16
1647	5/9–5/12/85	Lebanon	Fourth	17	17,17
1724	2/6–2/9/86	Chad	Fourth	17–18	—
	2/14–2/18/86	Afghanistan			—
	3/12–3/15/86				—
1739	6/2–6/5/86	Middle East	Fourth	18	—
1747	6/1–6/6/86	Middle East	Third	18	14,18
1756	6/20–6/24/86	Afghanistan	Fourth	18	—
	6/24–7/2/86	Central America			—
	7/29–8/4/86	Afghanistan			—
1770	9/24–10/2/86	NATO maneuvers	Fifth	18–19	15,19
1773	9/22–10/2/86	NATO maneuvers	Fourth	18–19	15,19
	10/18–10/21/86	Afghanistan			—
1792	1/2–1/5/87	Afghanistan	Fourth	27–28	20,28
1810	12/26–12/29/86	Gulf War	Fifth	19	—
	2/7–2/16/87	Afghanistan		31	—
1811	1/21–1/29/87	Gulf War	Fourth	27–28	—
	2/10–2/13/87	Middle East (Southern Lebanon).		28	—
1824	3/31–4/4/87	West coast U.S.A.	Fourth	28–29	21,29
1847	6/15–6/20/87	Afghanistan	Fourth	29	—
1893	11/25–12/3/87	Gulf War	Fourth	30	22,30
1895	11/26/87	Diego Garcia	Third	30–31	—

Notes:
1. This is a listing of references to possible target areas for photographic reconnaissance compiled from Nicholas Johnson's annual The Soviet Year In Space reviews published by Teledyne Brown Engineering, Colorado Springs, CO.
2. The fourth column indicates the type of satellite by third generation, high resolution, fourth or fifth generations as defined in the three preceding tables.
3. The fifth column gives the page numbers, in the annual review for the year of the period of observation, on which the relevant text appears.
4. The sixth column gives the figure number, followed by the page number, in the annual review for the year of the period of observation, on which the accompanying figure, if any, appears.
5. Table prepared for the Congressional Research Service by G. E. Perry.

aircraft carriers in the proximity of the U.S.S.R. coastline . . . represents an extremely provocative and hence destabilizing situation," Alexei Arbatov said that the Soviets did not believe that the monitoring of those aircraft carriers and maintaining the capability to oppose them in the event of war, was a destabilizing function.[8]

There were no RORSAT launches in 1983 as the Soviets endeavored to perfect the systems which had led to the failure of Cosmos 1402 at the end of 1982. The first satellite to appear when the program resumed in mid-1984 was Cosmos 1579, which operated normally for three months before being raised to the "safe", 104 minute orbit where the reactor fuel core was separated. At launch, the orbital plane of Cosmos 1579 was approximately 150° away from the orbital plane of Cosmos 1507 and Cosmos 1567, the two

[8] *Ibid.*

EORSATs with which it collaborated, perpetuating the pattern established with earlier joint missions and noted in the relevant section of chapter 1.

Cosmos 1607 was launched one month later and was again operational for three months before being raised. Its orbital plane, at launch, was the usual 150° behind the orbital plane of Cosmos 1567 and Cosmos 1588, which had replaced Cosmos 1507 as an operational EORSAT.

There was a sixth month gap before the next launch in the series, Cosmos 1670, which was joined three weeks later by Cosmos 1677. These two operated in concert, being co-planar with a 25.6 minute difference between the times of their ascending nodes producing a track-separation of something more than 6° At launch, the orbital plane of Cosmos 1670 was 150° away from that of Cosmos 1567 and Cosmos 1646, the operational pair of EORSATs. Their operational lives ended on consecutive days in October, 1985, after mission durations of one week less than three months and two months respectively. This was the only joint mission in the period under consideration and only the second time that a pair of RORSATs and a pair of EORSATs had operated together.

Cosmos 1736, launched in March 1986, also operated for three months. Its orbital plane at launch was 137° behind that of Cosmos 1735 and 159° behind that of the older Cosmos 1682, the operational EORSAT pair.

Cosmos 1771, launched two months after Cosmos 1736 was raised, flew for just less than two months before it was itself raised. At launch, its orbital plane was approximately 150° behind that of Cosmos 1735.

Cosmos 1860 operated for less than six weeks in mid-1987. Although several EORSATs were operational when it was launched on June 18, it was obviously paired with Cosmos 1834, the most recently launched, by virtue of the 142° spacing between their orbital planes.

Cosmos 1900 launched at the end of the year differed in two major respects from the accustomed pattern. Not only was its orbital period slightly higher than the usual 89.65 minutes but its orbital plane was some 30° ahead of that of EORSATs Cosmos 1834 and Cosmos 1890—approximately 180° away from where it might have been expected. Cosmos 1900 appeared set to approach or even break the mission-duration record of 135 days, set by Cosmos 1365 in 1982. However, this was not to be. It made its last orbital correction on April 10, 1988, 124 days after launch and thereafter entered a regime of natural decay. Following speculation by Western media that it was out of control,[9] the Soviets admitted that Cosmos 1900 had a nuclear power plant on board. The report continued:

> According to competent Soviet organizations radio contact with the satellite was lost in April 1988. The satellite is continuing in its oriented flight and the main service systems are functioning according to the program. The satellite will fly in orbit till August-September, after which it will cease to exist. The satellite, Cosmos 1900 has systems

[9] *News at Ten*, Independent Television News Ltd., London, 2100 GMT, May 10, 1988.

> ensuring radiation safety on completion of the flight. The flight of satellite Cosmos 1900 is being constantly monitored.[10]

A later report, emphasizing that the nuclear-powered satellite would not pose a radiation threat when it re-entered the Earth's atmosphere, enlarged on the systems for ensuring radiation safety. The nuclear power plant would be withdrawn from the spacecraft on radio command from the Earth or "automatically when the satellite's systems reach pre-set levels of operation." It continued:

> If the equipment for automatic withdrawal of the power plant and placing it in a high orbit fails, a system for the separation of the nuclear reactor into parts is activated on the entry of the satellite into the atmosphere. This system ensures a radiation situation within the limits recommended by the International Committee on Radiological Protection.[11]

The report concluded by saying that the satellite continued its attitude-controlled flight and would enter the atmosphere not earlier than August-September.

As of mid-July 1988, visual observations confirmed that the satellite's attitude remained stable. Although the satellite is not responding to radio commands from Earth it is possible that it still transmits data according to the program in the onboard memory at the time of loss of radio contact. Initial calculations, based on the assumption that Cosmos 1900 would retain a stable attitude until decay, suggested a decay around mid-October. However, if the satellite loses attitude stability and begins to tumble, as did Cosmos 954 on January 6, 1978, the decay-rate will increased markedly. It may be that the Soviets can predict a time at which attitude control could be lost due to the exhaustion of propellant and that accounts for their estimate of an earlier decay-date. It remains to be seen whether or not the reactor and the fuel core can be separated. One interpretation of the second official announcement is that the onset of increased and erratic drag in the upper layers of the atmosphere, prior to decay, will trigger the automatic separation system.

Table 43 lists the RORSAT launches in the Cosmos series from 1984 through 1987.

ELECTRONIC INTELLIGENCE GATHERING (ELINT)

New developments in hardware and mission profiles appeared in both sub-sets of electronic intelligence gathering Cosmos satellites during the period from 1984 through 1987. Electronic ocean reconnaissance satellites (EORSATs) continued to operate in conjunction with the RORSATs described in the preceding section. The passive ELINT satellites, launched by the F-2 from Plesetsk, were joined by an even heavier class, launched from Tyuratam, initially by the D-1e and subsequently by the new J-1.

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[10] *TASS*, 1100 GMT, May 13, 1988.
[11] *TASS*, 0746 GMT, June 8, 1988.

TABLE 43.—COSMOS RADAR OCEAN RECONNAISSANCE SATELLITES RORSATS: 1984–1987

	Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period	Raised	Life
1579	84–69A	6/29/84	264	250	65.0	89.7	9/26/84	90
			987	902	65.1	104.0		
1607	84–112A	10/31/84	263	251	65.0	89.7	2/1/85	93
			997	909	65.0	104.1		
1670	85–64A	8/1/85	264	252	65.0	89.7	10/22/85	83
			989	898	64.7	103.9		
1677	85–75A	8/23/85	263	251	65.0	89.7	10/23/85	60
			987	917	64.9	104.1		
1736	86–24A	3/21/86	266	246	65.0	89.6	6/21/86	92
			1012	925	65.0	104.5		
1771	86–62A	8/20/86	265	251	65.0	89.7	10/15/86	56
			999	915	65.0	104.2		
1860	87–52A	6/18/87	254	250	65.0	89.7	7/28/87	40
			953	945	65.0	104.0		
1900	87–101A	12/12/87	271	256	65.0	89.8	Decaying	124

Notes:
1. All satellites were launched from Tyuratam by the F–1m.
2. Apogee and perigee heights in kilometers, inclination in degrees, orbital period in minutes, and lifetime to raising to the "safe" orbit in integer days.
3. Orbital data in the second line of each entry refers to the "safe" orbit.
4. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
5. Table prepared for the Congressional Research Service by G. E. Perry.

Eorsats

An analysis of the philosophy of joint operations between RORSATs and EORSATs concludes that a pair of RORSATs and a pair of EORSATs appear to be a minimum constellation for reliable ocean surveillance.[12] The ground tracks of a typical RORSAT pair are separated by some 500 km and 45° latitude and the corresponding separation for the higher EORSATs is some 920 km. When ascending passes of RORSATs are phased with descending passes of EORSATs, a naval target at that latitude could be observed by all four satellites within the space of one hour.[13] A newspaper report estimates that EORSATs are capable of providing target data of about 2-km accuracy to antiship missile platforms and that the less capable RORSATs can probably detect destroyers in good weather and aircraft carriers in rough seas.[14]

The 93.3 minute orbital period chosen for the original EORSAT operations produced, at the 65° inclination, a repeating pattern of ground tracks after 61 orbits every fourth day, defining a set of ascending node locations peculiar to this class of satellite. In 1983, Cosmos 1507 was launched with its orbital plane ahead of that of Cosmos 1461 but, because it was crossing the Equator half an orbit earlier than Cosmos 1461, it had the same set of ascending node locations. These two EORSATs were still operational at the beginning of 1984.

The joint operation ended on January 30, 1984, when Cosmos 1461 maneuvered into an eccentric orbit with a period in excess of 99 minutes. When Cosmos 1567 joined Cosmos 1507 at the end of

[12] Johnson, N. L. *Soviet Ocean Reconnaissance Threat from Space.* International Counter Measures Handbook, Palo Alto, CA., E.W. Communications Inc., 1988. p. 103–109.
[13] *Ibid.*
[14] Anderson, J. *Washington Post,* Feb. 11, 1985. p. C12.

May the phasing was only one quarter of an orbit instead of one half. However, shortly afterwards, the orbital period of Cosmos 1507 began to increase and it would seem that Cosmos 1567 was launched to replace Cosmos 1507 rather than collaborate with it. When Cosmos 1588 was launched two months later it re-established the familiar half-orbit phasing with Cosmos 1567.

Cosmos 1625 was launched 33° out of plane with Cosmos 1567 and Cosmos 1588 in order to place it 145° away from the plane of the RORSAT Cosmos 1607. However, a re-start failure of the upper stage left the satellite in an eccentric orbit with a 120 km perigee from which it decayed naturally after two days. This failure may have prompted the termination of Cosmos 1607's mission, although it had been operational for three months.

With no RORSAT active at the time, Cosmos 1646 was launched practically co-planar with Cosmos 1567 and Cosmos 1588, crossing the Equator roughly midway between them. This was the first time that three EORSATs had been operational simultaneously. Cosmos 1588 entered a regime of natural decay in July, 1985, and gradually moved off station. At the same time the station-keeping regime between Cosmos 1567 and Cosmos 1646 was relaxed.

When Cosmos 1682 was launched two months later it was seen to be a direct replacement for Cosmos 1588 and synchronized station-keeping with Cosmos 1646 was established. During the period of joint operation of the RORSAT pair, Cosmos 1670 and Cosmos 1677, four, and possibly five (if Cosmos 1567 is included) ocean surveillance satellites were simultaneously operational. Cosmos 1567 finally entered a regime of natural decay at the end of November, having established a new mission-duration record approaching 18 months.

February 1986 saw several interesting features in the EORSAT program. Cosmos 1682 entered an eccentric orbit while maintaining its orbital period at 93.3 minutes to preserve its sub-set of ascending node locations. Although the eccentricity of the orbit steadily decreased, orbital period was maintained by maneuvers until October when the orbit was permitted to decay naturally until the satellite fragmented on December 18. Cosmos 1588 fragmented on February 23 and on the following day Cosmos 1646 was retired from active service, leaving Cosmos 1682 with its new mission profile as the only active EORSAT. A new EORSAT, Cosmos 1735, was launched on February 27. This was the first EORSAT to fly in a slightly lower orbit with a period of 92.8 minutes, producing a three-day ground track repeat pattern after 46 orbits. Location of its orbital plane 20° away from that of Cosmos 1682 ensured that its sub-set of ascending nodes coincided with those of Cosmos 1682 every twelfth day.

Cosmos 1737, the next EORSAT, was the only ocean surveillance satellite to depart from the 65° inclination. Its 93.0 minute orbital period at 73.4° inclination produced the same sub-set of ascending node locations as those of Cosmos 1735. Cosmos 1737 was de-orbited after 253 days on December 3—the only instance of de-orbiting of an EORSAT. Such a mission profile has not been repeated as of mid-1988.

Cosmos 1769, launched in August 1986, reverted to the four-day repeating pattern and shared the ascending node locations of Cosmos 1682.

Cosmos 1834 was launched co-planar with Cosmos 1735 with the lower orbital period of 92.8 minutes and the three-day ground track repeat pattern. Although it was one third of an orbit ahead of Cosmos 1735, it shared the same sub-set of ascending node locations. Less than two weeks later, Cosmos 1735 maneuvered to the higher orbit with the four-day ground track repeat pattern. The timing of this maneuver was such as to ensure that its new sub-set of ascending node locations was the same as that of Cosmos 1769 due to a 32° plane separation and a 36.5 minute difference in the times of their Equator crossings. Cosmos 1769 was retired from active service in August and disintegrated six weeks later. Cosmos 1735 ceased activity at the end of September and began to decay naturally at the beginning of November having set a new mission-duration record of 20 months.

Cosmos 1890 joined Cosmos 1834 in October once more establishing a co-planar pair with ascending nodes separated by one third of an orbital period and these two were still active at the end of the year, by which time Cosmos 1646 had fragmented.

Two F-1m launches in 1987 had all the characteristics of EORSAT missions save in one respect—the height, and consequently the period, of their orbits. Cosmos 1818 and Cosmos 1867, launched in February and July, fly at heights between 786 and 800 km with orbital periods of 100.7 minutes. The 120° spacing between their orbital planes suggests an eventual constellation of three such satellites.

The 100.76 minute period at 65° inclination produces a seven-day ground track repeat pattern every 99 orbits. Shortly before the launch of Cosmos 1867, Cosmos 1818 lowered its orbital period to 100.74 minutes, thereby destroying its perfect ground track repeat pattern. However, this did not signify the deactivation of Cosmos 1818, which has continued to maintain its new orbit through mid-1988.

An indirect reference to the new mission profile came in testimony to the U.S. Congress by Dr. Lawrence W. Woodruff, Deputy Under Secretary of Defense for strategic and theater nuclear forces, who claimed that Soviet satellites were now flying at altitudes higher than the ceiling proposed for the now abandoned U.S. F-15 launched miniature homing vehicle (MHV) ASAT.[15]

At the December 1987, U.S./Soviet summit, the Soviets offered use of "cutting-edge ocean surveillance technology for verification.." [16] General Secretary Mikhail Gorbachev said his nation's technological advancements in national technical means (remote surveillance from space) had provided the capability to verify the presence of nuclear sea-launched cruise missiles (SLCMs) both on surface ships and submarines, "without any inspection on the vessels." He said that he had offered to share these Soviet advance-

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[15] Aerospace Daily, Mar. 13, 1987, p. 378.
[16] *Aviation Week and Space Technology*, Dec. 14, 1987, p. 18.

ments with the U.S., to demonstrate their usefulness in solving the difficult SLCM verification problem.[17]

TABLE 44.—COSMOS ELECTRONIC OCEAN RECONNAISSANCE SATELLITES EORSATS: 1984–1987

	Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period	Down
1567	84–53A	5/30/84	441	431	65.0	93.3	
1588	84–83A	8/7/84	446	426	65.0	93.3	2/23/86*
1625	85–08A	1/23/85	392	120	65.0	89.6	1/25/85
1646	85–30A	4/18/85	444	428	65.1	93.3	11/20/87*
1682	85–82A	9/19/85	443	429	65.0	93.3	12/18/86*
1735	86–21A	2/27/86	418	403	65.0	92.8	
1769	86–59A	8/4/86	444	429	65.0	93.3	9/21/87*
1834	87–31A	4/8/87	418	404	65.0	92.8	
1890	87–86A	10/10/87	417	403	65.0	92.8	
1737	86–25A	3/25/86	428	413	73.4	93.0	12/3/86
1818	87–11A	2/1/87	800	786	65.0	100.7	
1867	87–60A	7/10/87	801	786	65.0	100.7	

Notes:
1. All satellites were launched from Tyuratam by the F–1m.
2. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Satellites which have been deliberately fragmented at the end of their useful lives are indicated by an asterisk following the date in the final column.
5. Table prepared for the Congressional Research Service by G. E. Perry.

Elint

By the beginning of 1984, the global role of electronic intelligence gathering had passed to the second generation heavy ELINT satellites launched from Plesetsk by the F–2.

Twenty of these satellites were successfully launched in the period from 1984 through 1987 and these are listed in table 45.

At the beginning of 1984 only four of six planes separated by 60° in right ascension of ascending node were occupied, but the first two launches of the series in 1984, Cosmos 1536 and Cosmos 1544, filled the remaining gaps.

Two instances of consecutive launches in the series into the same orbital plane during 1985 caused speculation about the reliability of these satellites. It was customary for Western analysts to presume that a launch to a particular plane implied that the previous satellite launched into that plane had failed or was about to fail. There was only a four-month interval between the launches of Cosmos 1633 and 1666 and even less between the launches of Cosmos 1674 and Cosmos 1703.

Sven Grahn of the Kettering Group had identified transmission frequencies of either 153.42 or 153.48 MHz for this class of satellite and, in 1985, Clifford Ranft, another Kettering Group member, embarked on a program of routine monitoring of these frequencies from Cambridge, England, with the aim of determining their operational status. He quickly established that Cosmos 1633 and Cosmos 1666 were both operational and transmitting on 153.48 MHz and that Cosmos 1674 continued to transmit on 153.42 MHz even after Cosmos 1703 began transmitting on that frequency.

[17] *Ibid.*

TABLE 45.—COSMOS ELINT SATELLITE LAUNCHES FROM PLESETSK WITH THE F–2: 1984–1987

Cosmos number and designator		Launch	Apogee	Perigee	Inclination	Orbital period
1536	84–13A	2/8/84	665	634	82.5	97.7
1544	84–27A	3/15/84	664	634	82.5	97.7
1606	84–111A	10/18/84	664	632	82.5	97.7
1626	85–09A	1/24/85	664	630	82.5	97.7
1633	85–20A	3/5/85	658	637	82.5	97.7
1666	85–58A	7/8/85	666	634	82.5	97.7
1674	85–69A	8/8/85	664	632	82.5	97.7
1703	85–108A	11/22/85	666	635	82.5	97.7
1707	85–113A	12/12/85	665	634	82.5	97.7
1726	86–06A	1/17/86	663	632	82.5	97.7
1733	86–18A	2/19/86	662	633	82.5	97.7
1743	86–34A	5/15/86	665	628	82.6	97.7
1758	86–46A	6/12/86	669	631	82.5	97.7
1782	86–74A	9/30/86	664	636	82.5	97.7
1805	86–97A	12/10/86	662	635	82.5	97.7
1812	87–03A	1/14/87	664	635	82.5	97.8
1825	87–24A	3/3/87	664	633	82.5	97.8
1842	87–38A	4/27/87	666	634	82.5	97.8
1862	87–55A	7/1/87	667	633	82.5	97.8
1892	87–88A	10/20/87	664	635	82.5	97.8

Notes:
1. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
2. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
3. Table prepared for the Congressional Research Service by G. E. Perry.

Similar observations by Ranft of the store-dump communications satellites in the Cosmos series revealed that, in both of these systems, there could be more than one satellite active in a given plane at any one time. These observations, coupled with observations of the reactivation of navigation satellites which had been retired on replacement to fill gaps caused by failures of newer satellites, discounted the belief that the high launch-rate for these types of Soviet satellites is dictated by their unreliability and technological inferiority by comparison with their Western counterparta.[18]

The launch of Cosmos 1805, at the end of 1986, into an orbital plane situated midway between planes of the main constellation, raised the possibility that it could be the forerunner of a new constellation with a plane-separation of 90° but subsequent launches did not support that theory. Cosmos 1892, launched in October, 1987, also entered a plane between the main planes but no further inter-plane launches were made during the first half of 1988 although three more satellites were launched into the main planes.

Table 46 shows the replacement sequence of the Cosmos satellites in the F–2 launched ELINT system in their respective planes, together with the transmission frequencies, where known, for the period from 1984 through 1987.

Three routine replacement launches during the first half of 1988 placed Cosmos 1908, Cosmos 1933 and Cosmos 1953 into planes 6, 2 and 3 respectively.

What might be considered as a third generation, even heavier, ELINT satellite[19] appeared in 1984 with the launch of Cosmos 1603

[18] Perry, G. E. and C. H. Ranft. *Aviation Week and Space Technology*, Oct. 20, 1986. p. 160.
[19] *Aviation Week and Space Technology*, Jan. 14, 1985, p. 19–20.

TABLE 46.—ORBITAL PLANE LOCATIONS OF SECOND GENERATION COSMOS HEAVY ELINT SATELLITES: 1984–1987

	1	2	3	4	5	6
	1455	1515	—	1408	1470	—
1984			1536[2]			
						1544[8]
	1606					
1985				1626		
					1633[8]	
					1666[8]	
			1674[2]			
			1703[2]			
		1707[2]				
1986	1726[8]					
						1733[2]
				1743[8]		
					1758[8]	
						1782[2]
					1805[2]	
1987	1812[2]					
				1825[8]		
		1842[2]				
			1862[8]			
				1892[2]		

Notes:
1. Orbital planes are separated by 600 in right ascension of the ascending node.
2. The constellation of second generation heavy ELINT satellites began to be established in 1981 and was completed in 1984. 3.Cosmos numbers immediately below the double line at the top of the table indicate the operational status as of December 31, 1983.
3. Cosmos 1805 and 1892 entered planes situated between those of the main constellation.
4. Satellites transmit on 153.42 and 153.48 MHz. Frequencies identified by C.H. Ranft are indicated by superscripts 2 or 8 respectively.
5. Table prepared for the Congressional Research Service by G. E. Perry.

by a D-1e from Tyuratam. From the usual initial orbit at 51.6° with an 88 minute period, characteristic of this launch vehicle at the time, it maneuvered to an inclination of 66.6° with a 101.6 minute period to its final orbit at 71° inclination and 102 minute period, near circular at 850 km. In this orbit the ground track repeated itself closely at daily intervals after every 14 orbits of the Earth.

Cosmos 1656, launched eight months later, repeated the launch profile although failing to attain such a circular final orbit. The orbital plane separation of 45° suggested that these were the first in a new constellation of four or eight planes to provide global coverage.

Table 47 lists the D-1e launched ELINT satellites in the Cosmos series from 1984 through 1985.

TABLE 47.—COSMOS ELINT SATELLITE LAUNCHES FROM TYURATAM WITH THE D1e: 1984–1985

Cosmos number and designator		Launch date	Apogee	Perigee	Inclination	Orbital period
1603	84-106A	9/28/84	856	850	71.0	102.0
1656	85-42A	5/30/85	861	807	71.1	101.6

Notes:
1. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
2. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
3. Table prepared for the Congressional Research Service by G. E. Perry.

When Cosmos 1697 was launched on October 22, 1985, it was placed into its 71°, near-circular 102 minute orbit without any objects being tracked in the 51.6° or 66.6° intermediate orbits employed by Cosmos 1603 and Cosmos 1656. Visual observations showed that Cosmos 1697 was less bright than its rocket body whereas Cosmos 1603 and its rocket body had appeared of comparable brightness.[20] NORAD radar cross-sections[21] of 44.10, 31.72 and 16.36 square meters and the Kettering Group's Max White's observation that under similar viewing conditions, Cosmos 1697 was less bright than Cosmos 1603, suggested that Cosmos 1697 was not as large as its two predecessors. NORAD sensors detected four fragments associated with the launch in addition to the rocket body. These had the same perigee heights as Cosmos 1697 but apogees some 300 km higher. No additional fragments had been detected from the two D–1e launches and such fragments were to become characteristic of launches of the new J–1 launch vehicle. In 1986, the Defense Intelligence Agency (DIA) confirmed that this was the first orbital test of what they referred to as the SL–X–16.[22] The orbital plane of Cosmos 1697 was approximately one quarter of the way between those of Cosmos 1656 and Cosmos 1603.

At the end of 1985, Cosmos 1714 was launched with a 71° inclination. Had the launch been successful it would have placed Cosmos 1714 into a near-circular 102 minute orbit in a plane separated by 90° from that of Cosmos 1603. However, the final stage failed to fire at apogee to circularize the orbit and it decayed naturally in the Earth's atmosphere at the end of February, 1986. Four additional fragments were also detected with this launch.

There were no similar launches during 1986 following this failure but the program resumed in 1987 with two launches separated by two months. Cosmos 1833 and Cosmos 1844 were placed in orbital planes separated by 130° and exhibited a small maneuvering capability. By mid-1988 both satellites had adjusted their orbital periods to 101.98 minutes producing a perfect repetition of ground tracks on a daily basis. Cosmos 1943, launched on May 15, 1988, had an orbital period of only 101.96 minutes which caused its ground tracks to precess eastward at a rate of 0.1° of longitude per day. Its ascending nodes were very close to those of Cosmos 1844 but its orbital plane was 120° away from that of Cosmos 1833.

Table 48 lists the J–1 launched ELINT satellites in the Cosmos series from 1984 through 1987.

Early Warning of Missile and Space Launches

Early warning satellites in the Cosmos series occupy nine planes with 40° inter-plane spacings providing the necessary global coverage. Although the constellation of nine planes was completed with the launch of Cosmos 1367 in 1982, all planes had never been simultaneously operational through the end of 1983. Ascending nodes of the semi-synchronous, highly eccentric, orbits were located

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[20] *Aerospace Daily*, Oct. 24, 1984, p. 290–291.

[21] Satellite Catalog, HQ USSPACECOM/J3SOS, Cheyenne Mountain Complex, CO., p. 64, 56 and 47.

[22] Letter to C. P. Vick from DIA Public Affairs, June 11, 1986.

TABLE 48.—COSMOS ELINT SATELLITE LAUNCHES FROM TYURATAM WITH THE J1: 1984–1987

	Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period
1697	85–97A	10/22/85	854	850	71.0	102.0
1714	85–121A	12/28/85	853	163	71.0	94.8
1833	87–27A	3/18/87	852	849	71.0	102 .0
1844	87–41A	5/13/87	853	849	71.0	102.0

Notes:
1. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
2. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
3. Table prepared for the Congressional Research Service by G. E. Perry.

close to 60°W and 240°W, having been relocated from 90°W and 270°W in 1981.

Despite an annual launch rate of seven satellites per year, it was not until 1986 that all nine planes were occupied by an operational satellite and, even then, one of those was not working in conjunction with the others. Full operational status was not attained until 1987, 15 years after the introduction of the program.

Table 49 lists the early warning Cosmos satellite launches from 1984 through 1987.

TABLE 49.—COSMOS EARLY WARNING SATELLITES: 1984–987

	Cosmos number and designator	Launch date	Apogee	Perigee	Inclination	Orbital period
1541	84–24A	3/6/84	39747	599	62.9	717.6
1547	84–33A	4/4/84	39750	594	62.9	717.6
1569	84–55A	6/6/84	39758	594	62.9	717.7
1581	84–71A	7/3/84	39723	621	63.0	717.6
1586	84–79A	8/2/84	39741	610	63.0	717.7
1596	84–96A	9/7/84	39728	626	62.9	717.8
1604	84–107A	10/4/84	39722	598	62.9	717.1
1658	85–45A	6/11/85	39758	592	62.9	717.7
1661	85–49A	6/18/85	39761	586	63.0	717.6
1675	85–71A	8/12/85	39732	602	62.9	717.4
1684	85–84A	9/24/85	39762	583	62.9	717.6
1687	85–88A	9/30/85	39710	626	63.0	717.4
1698	85–98A	10/22/85	39726	605	62.9	717.3
1701	85–105A	11/9/85	39719	619	63.0	717.5
1729	86–11A	2/1/86	39733	633	62.9	718.0
1761	86–50A	7/5/86	39757	585	62.9	717.5
1774	86–65A	8/28/86	39723	616	63.0	717.5
1783	86–75A	10/3/86	20057	597	62.8	358.1
1785	86–78A	10/15/86	39759	604	63.1	718.0
1793	86–91A	11/20/86	39755	594	63.0	717.7
1806	86–98A	12/12/86	39730	619	62.9	717.7
1849	87–48A	6/4/87	39728	627	62.9	717.8
1851	87–50A	6/12/87	39743	611	62.9	717.8
1903	87–10A	12/2/87	39757	588	63.0	717.6

Notes:
1. All satellites were launched from Plesetsk by the A–2e.
2. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Due to the premature shut-down of the final stage of the A–2e, Cosmos 1783 failed to attain the intended orbit and was never operational.
5. Table prepared for the Congressional Research Service by G. E. Perry.

Cosmos 1317, which was launched in 1981, apparently broke up in January 1984, with NORAD cataloging three fragments in the only instance of fragmentation of such a satellite.

Replacement satellites were launched in every month, except May, during the period from March through October, 1984. All were launched into different orbital planes. Cosmos 1317 was not replaced until July. One month earlier, Cosmos 1518, which had been launched at the end of 1983, was lowered and permitted to drift off station after only five months of operation and was replaced, five days later, by Cosmos 1569. At the end of the year a replacement was still awaited for Cosmos 1261, which was launched in 1981 and failed in under a month, and whose intended replacements, Cosmos 1285 and Cosmos 1481, had never stabilized their ground tracks.

The long-awaited replacement came on June 11, 1985, with Cosmos 1658, the first of seven early warning launches in less than 5 months. The launch of Cosmos 1661, seven days later, reverted to the old launch profile with the higher period transfer orbit, last used for Cosmos 1317 in 1981, and stabilized its ground track with ascending nodes close to the original 1981 locations. Cosmos 1604 remained on station in that plane until it began to drift off in October and, at end of year, Cosmos 1661 was the only satellite in the nine planes with its ascending nodes displaced from the rest.

Cosmos 1687 failed in January, 1986, after only three months of operation and was not replaced until November when Cosmos 1793 was launched.

At the beginning of February, 1986, Cosmos 1729 was launched to replace Cosmos 1569, which had been in orbit for 20 months and then began to drift off station. Cosmos 1675, which had been replaced by Cosmos 1701 some three months earlier, also began to drift off station around this time. Cosmos 1698 was replaced by Cosmos 1761 in July after less than one year of operation. Cosmos 1547, which had failed nearly a year earlier, was replaced by Cosmos 1774 in August.

A premature shut-down of the final stage of the A-2e launch vehicle left Cosmos 1783 in an orbit with approximately half the desired orbital period and apogee rendering it useless for its intended role. Its orbital plane coincided with that of Cosmos 1661 so this still left that plane without an operational satellite with ascending nodes co-located with the others. Cosmos 1785, launched only 12 days later, was not a replacement for Cosmos 1783 but replaced the aging Cosmos 1596 after an operational life of more than two years.

Cosmos 1806 was launched on December 12 to replace Cosmos 1729, launched earlier in the year. On the following day Cosmos 1729 was maneuvered to relocate its ascending nodes close to those of Cosmos 1661. By the end of the year it had re-stabilized its ground tracks and eight of the planes contained satellites with ascending nodes in the locations adopted during 1981 while the ninth plane and one other were occupied by operational satellites with ascending nodes at the original locations used for the system.

The ninth plane was filled with a satellite having ascending nodes co-located with the others in June, 1987, but Cosmos 1661, with the displaced ascending nodes in that plane, remained active through mid-1988, as did Cosmos 1729. It is possible that these two

satellites function as in-orbit spares which could be recalled to full operational status should the need arise.

The only other launches in 1987, Cosmos 1851 and Cosmos 1903 in June and December, were routine replacements of satellites which had been operational for two years or more. Therefore, since mid-1987, the Soviet Union could be considered to possess a fully operational constellation of satellites, with on-orbit spares, for the early warning of satellite and missile launches.

Table 50 shows the replacement sequence of the early warning Cosmos satellites in their respective planes.

TABLE 50.—REPLACEMENT SEQUENCE OF COSMOS EARLY WARNING SATELLITES: 1984–1987

	1	2	3	4	5	6	7	7	9
	1409	1278	1456	1518	1261	1382	1317	1348	1367
		1541							
1						1547			
9				1569					
8							1581		
4			1586						
								1596	
									1604
					1658				
1									1661
9							1675		
8			1684						
5	1687								
		1698							
							1701		
				1729					
1		1761							
9						1774			
8									(1783)
6								1785	
	1793								
				1806					
1									1849
9					1851				
8							1903		
7									

Notes:
1. Orbital planes are separated by 900 in right ascension of the ascending node.
2. Cosmos numbers immediately below the double line at the top of the table indicate the operational status as of Dec. 31, 1983.
3. The ground-tracks of Cosmos 1285 and 1481, which should have replaced Cosmos 1261, were never stabilized.
4. The ascending node of Cosmos 1661 was situated in the constellation's pre-1981 location.
5. The ascending node of Cosmos 1729 was moved to the constellation's pre-1981 location at the end of 1986.
6. Due to the premature shut-down of the final stage of the A–2e, Cosmos 1783 failed to attain the intended orbit and was never operational.
7. Table prepared for the Congressional Research Service by G. E. Perry.

Communications, Command and Control (C^3)

SEMI-SYNCHRONOUS SATELLITES AND GEOSYNCHRONOUS SATELLITES

It was noted in the historical summary in chapter X that Molniya 1 satellites in semi-synchronous orbits were believed to primarily serve governmental and military needs. Molniya 1 satellites continued to be launched during the period 1984 through 1986. No such satellites were launched in 1987 but there were two further launches in the series during the first half of 1988. Details of the

Molniya launches are given in chapter X. The possible use of Raduga geosynchronous satellites for military communications has also been noted in earlier chapters. Some geosynchronous Cosmos satellites may also serve in a similar capacity.

TACTICAL AND THEATER COMMUNICATIONS

Octuple Launches

There were seven octuple launches from 1984 through 1987. These are listed in table 51. As is usual, all launches placed their multiple payloads into the same orbital plane as that used for the original launch of the sub-set in 1970.

Evidence supporting the view that the payloads in a single launch are identical is to be found in the radar cross-sections determined by the AN/FPS–85 radar at Eglin A.F.B., Florida, and given in the U.S. Space Command's *Satellite Catalog*. With two exceptions, the values given for the 56 payloads resulting from these launches lie between 0.84 and 2.01 square meters. The 8.18 and 4.66 square meters given for Cosmos 1642 and Cosmos 1750 respectively are so different from the others as to be suspect.

An alternative role has been suggested for the octuple payloads based on a description of the Latvian University's laser rangefinder reported in the geodesy section of chapter 3. In that section, the writer suggested that the "target" of the Riga laser was the 60 cm-diameter, U.S. LAGEOS satellite. Nicholas Johnson chose to identify the "targets" as the octuple payloads.[23] One of his reasons for this was the statement in the *TASS* announcement which ascribed an orbital velocity in excess of 7 km/s, consistent with the 7.1 km/s of the octuple payloads, to the "target". The 5.7 km/s orbital velocity of LAGEOS clearly is not consistent with the *TASS* figure. The root of the disagreement is an inconsistency in the *TASS* data. In addition to the orbital velocity, a value of "6,000 to 7,000 km" was given for the height of the "target" satellite(s) above the Earth's surface. Orbital velocities at these heights are 5.68 and 5.46 km/s respectively and the mean height of the LAGEOS orbit is just less than 6,000 km. A contributing factor to Johnson's analysis was an article on space methods in geodesy which described the use of identical satellites in a single orbit for geodetic purposes.[24]

Sextuple Launches

A new sub-set of Cosmos satellites made its appearance with two launches in 1985 and a further two launches in 1987. In this subset, six payloads are launched at a time by an F–2 from Plesetsk using a deployment mechanism closely resembling that of the C–1 octuple payload launches. Although it is by no means certain that these satellites have communications roles, they are considered here for convenience because of the similarity and because they were initially considered to be taking over the role of the octuple launched payloads.[25]

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[23] Johnson, N. L. *The Soviet Year in Space 1987*. Teledyne Brown Engineering, Colorado Springs, CO., 1988. p. 35.
[24] Mikisha, A. M. *Znaniye*, Sept. 1983.
[25] *Aerospace Daily*, Jan. 22, 1985, p. 108.

TABLE 51.—OCTUPLE LAUNCHES OF COSMOS TACTICAL COMMUNICATIONS SATELLITES: 1984–1987

Cosmos number and designator		Launch date	Apogee	Perigee	Inclination	Orbital period
1522–1529	84–01A–H	1/5/84	1494	1461	74.0	115.6
1559–1566	84–52A–H	5/28/84	1510	1471	74.0	115.8
1635–1642	85–23A–H	3/21/85	1513	1474	74.1	115.9
1716–1723	86–02A–H	1/9/86	1492	1465	74.0	115.5
1748–1755	86–42A–H	6/6/86	1470	1454	74.0	115.2
1794–1801	86–92A–H	11/21/86	1501	1467	74.0	115.6
1852–1859	87–51A–H	6/16/87	1501	1473	74.0	115.7

Notes:
1. All satellites were launched from Plesetsk by the C–1.
2. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

Whereas all octuple payloads had been placed into the same plane as that used for the original launch, the 1985 sextuple payloads were in planes which were nearly 180° apart. The first sextuple launch of 1987 was practically co-planar with the second of the 1985 launches, reviving thoughts of their taking over the octuple's role, but the second sextuple launch of 1987 was into a plane at 90° to the first. When the 1988 sextuple launch went into the same plane as the first of the 1987 launches, it began to look as if an operational constellation of 12 satellites in two mutually perpendicular planes was intended, although the mission remained undetermined.

In another difference from the octuple launches, radar cross-section evidence points to the 1985 sextuple payloads not being identical. Both launches produced two payloads with radar cross-sections of between 3.79 and 4.50 square meters with four smaller payloads having radar cross-sections of between 0.24 and 0.82 square meters. Five of the first sextuple payloads in 1987 had radar cross-sections varying between 4.32 and 5.66 square meters—comparable data for the sixth payload is not available—and a case could be made for them being identical. Values for five of the second sextuple payloads that year varied from 1.88 to 4.69 square meters, the sixth being undetermined.

On November 22, 1985, 44 days after launch, NORAD sensors cataloged nine fragments associated with Cosmos 1691, one of the two larger satellites from that launch and the last to be deployed. This is characteristic of some minor military missions thought to be for calibration of radars or exercising of ABM forces. No such event has been associated with multiple payload launches before or since that occasion.

Table 52 lists the sextuple payload launches in the Cosmos series from 1985 through 1987.

Covert Store--Dump

The covert store-dump constellation of Cosmos satellites was in the transitional phase of relocating the orbital planes at the beginning of 1984. During 1983, Cosmos 1452 and Cosmos 1503 had been placed in planes displaced by some 10° from the planes utilized prior to 1983.

TABLE 52.—SEXTUPLE LAUNCHES OF COSMOS SATELLITES: 1985–1987

Cosmos number and designator		Launch date	Apogee	Perigee	Inclination	Orbital period
1617–1622	85–03A–F	1/15/85	1414	1414	82.6	114.1
1690–1695	85–94A–F	10/9/85	1417	1382	82.6	113.8
1827–1832	87–26A–F	3/13/87	1412	1396	82.6	113.9
1875–1880	87–74A–F	9/7/87	1411	1387	82.6	113.8

Notes:
1. All satellites were launched from Plesetsk by the F-2.
2. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Cosmos 1691 disintegrated 11/22/85.
5. Table prepared for the Congressional Research Service by G. E. Perry.

Cosmos 1538, the first of the 1984 launches in this sub-set, completed the relocation and once more there were operational satellites in three planes spaced at 120° in right ascension.

When Clifford Ranft embarked on a program of routine monitoring of ELINT satellites on 153.42 and 153.48 MHz, he also investigated other frequencies at 60 kHz intervals from these to test the possibility of discovering further satellite signals. Before long he logged signals on 153.60 MHz and over a period of five days accumulated sufficient observations to establish possible values for the orbital periods which included 100.71 minutes. It was quickly confirmed that his new signals were emanating from the store-dump communications satellites in the Cosmos series.[26] Ranft later discovered that certain of these satellites transmitted on 153.66 MHz. His observations revealed that, as in the case of the ELINT satellites, there could be more than one satellite active in a given plane at any one time.

Table 53 lists the store-dump communications satellites in the Cosmos series from 1985 through 1987, with transmission frequencies where known.

TABLE 53.—COSMOS STORE-DUMP COMMUNICATIONS SATELLITES: 1984–1987

Cosmos number and designator		Launch date	Apogee	Perigee	Inclination	Orbital period
1538	84–19A	2/21/84	810	778	74.1	100.8
1570	84–56A	6/8/84	809	791	74.1	100.9
1624	85–06A	1/17/85	808	785	74.1	100.8
1680	85–79A	9/4/85	807	784	74.1	100.8
1741	86–30A	4/17/86	811	782	74.0	100.8
1763	86–52A	7/16/86	805	758	74.0	100.5
1777	86–70A	9/10/86	812	777	74.0	100.8
1814	87–06A	1/21/87	810	771	74.1	100.7
1850	87–49A	6/9/87	807	783	74.0	100.8
1898	87–98A	12/1/87	810	778	74.0	100.8

Notes:
1. All satellites were launched from Plesetsk by the C–1.
2. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. Table prepared for the Congressional Research Service by G. E. Perry.

[26] Perry, G. E. *Oscar News*, AMSAT–UK, Dec. 1987, p. 4–9.

Table 54 shows the replacement sequence of the Cosmos store-dump communications satellites in their respective planes, together with the transmission frequencies, where known, for the period 1984 through 1987.

Two routine replacement launches during the first half of 1988 placed Cosmos 1937 and Cosmos 1934 into planes 3' and 2' respectively.

TABLE 54.—ORBITAL PLANE LOCATIONS OF COSMOS STORE-DUMP COMMUNICATIONS SATELLITES: 1984–1987

	1	1'	2	2'	3	3'
	1420			1503[6]		1452
1984		1538[o]				
						1570[o]
1985						1624[o]
		1680[o]				
1986				1741[o]		
				1763[6]		
						1777[6]
1987		1814[o]				
				1850[o]		
						1898[6]

Notes:
1. Orbital planes are separated by 120° in right ascension of the ascending node.
2. Cosmos numbers immediately below the double line at the top of the table indicate the operational status as of Dec. 31, 1983.
3. Commencing in 1983 with Cosmos 1452 the orbital planes of the constellation were displaced by some 10° from their original locations. The repositioning was completed by Cosmos 1538 in 1984.
4. The orbital period of Cosmos 1763 is lower than those of the other members of the constellation, causing it to drift off station.
5. Satellites transmit on 153.60 and 153.66 MHz. Frequencies identified by C.H. Ranft are indicated by superscripts [o] or [6] respectively.
6. Table prepared for the Congressional Research Service by G. E. Perry.

Navigation

The military constellation of six satellites in planes with ascending nodes spaced at 30° in right ascension has operated throughout the period under consideration with routine replacements of aging satellites.

Table 55 lists the launches of Cosmos satellites in the military navigation system from 1984 through 1987.

All Soviet military navigation satellites transmit a 6,000-bit navigation message at a rate of 50 baud on frequencies which are unique to specific planes and are at 30 kHz intervals from the common 150.00 MHz frequency of the civil navigation satellites. The frequencies are stated in parentheses in the sub-headings which follow. A near-complete description of the message has been published elsewhere.[27]

Each plane takes a specific identity number from 1 through 6. Satellites which have been replaced and then subsequently re-activated to provide a back-up service and those which have just been launched and are in the pre-operational check-out phase may take

[27] Wood, C. D. and G. E. Perry. *Philosophical Transactions of the Royal Society of London*, Series A, 1980, p. 307–315. An abridged version of this paper was included as Annex 2 to Chapter 4 of the previous edition of this report [*Soviet Space Programs: 1976–80 (with supplementary data through 1983)*, Pt.3] p. 1027–1034.

TABLE 55.—COSMOS SATELLITES IN THE MILITARY NAVIGATION SYSTEM: 1984–1987

Payload name	Launch date	Apogee	Perigee	Inclination	Orbital period	Remarks
Cosmos 1531	1/11/84	1010	982	82.9	105.0	#2 [1386]
Cosmos 1535	2/2/84	1017	956	83.0	104.8	#3 [1428]
Cosmos 1550	5/11/84	1012	976	83.0	105.0	failure? [1535]; no transmissions monitored
Cosmos 1577	6/27/84	1011	959	83.0	104.8	#5 [1464]
Cosmos 1598	9/13/84	1016	970	82.9	104.0	#3[1535/1550?]
Cosmos 1605	10/11/84	1019	952	82.9	104.8	#4 [1459]
Cosmos 1610	11/15/84	1013	968	83.0	104.9	#2 [1531]
Cosmos 1627	2/1/85	1018	958	82.9	104.9	#1 [1448]
Cosmos 1634	3/14/85	1011	960	82.9	104.8	#6 [1513]
Cosmos 1704	11/28/85	1110	965	82.9	104.8	#3 [1598]
Cosmos 1709	12/19/85	1013	963	83.0	104.9	#2 [1610]
Cosmos 1725	1/16/86	1003	972	82.9	104.9	#5 [1577]
Cosmos 1745	5/23/86	1011	966	83.0	104.9	#1 [1627]
Cosmos 1759	6/18/86	1003	969	82.9	104.8	#6 [1634]
Cosmos 1802	11/24/86	1025	963	82.9	105.0	#4 [1605]
Cosmos 1808	12/17/86	1020	973	82.9	105.0	#3 [1598]
Cosmos 1821	2/18/87	1016	963	82.9	105.0	#5 [1725]
Cosmos 1864	6/6/87	1006	961	82.9	104.8	#5 [1821]
Cosmos 1891	10/14/87	1027	954	82.9	105.0	#6 [1759]
Cosmos 1904	12/23/87	1008	967	82.9	104.9	#2 [1709]

Notes:
1. All satellites launched by the C–1 booster from Plesetsk.
2. Numbers preceded by # indicate the identity numbers referred to in the satellites' navigation messages.
3. Numbers in brackets are the Cosmos numbers of satellites replaced by those listed.
4. Table prepared for the Congressional Research Service by G. E. Perry.

identity numbers of 7, 8 or 9. It is convenient to consider the history of each plane individually.

PLANE 1 (149.970 MHZ)

Cosmos 1448, launched on March 30, 1983, failed at the end of December, 1984. In an attempt to provide temporary coverage until it was replaced by Cosmos 1627 at the beginning of February 1985, the Soviets reactivated Cosmos 1535 in plane 3 and Cosmos 1464 in plane 5. Cosmos 1627 was replaced by Cosmos 1745 in mid-1986 and was still operational after two years.

PLANE 2 (149.910 MHZ)

The 18-month old Cosmos 1836 was replaced by Cosmos 1531 at the beginning of 1984. This, in turn, was replaced toward the end of that year by Cosmos 1610. After 13 months, Cosmos 1610 was replaced by Cosmos 1709, which remained operational for two years before being replaced by Cosmos 1904 at the end of 1987.

PLANE 3 (149.940 MHZ)

This plane has been plagued by misfortune. Cosmos 1333, which had been operational for a year, was replaced by Cosmos 1428 in January 1983 and assumed the temporary identity number 7. The normal weekly update of its ephemeris did not take place during the second week of July and subsequent observations revealed that the transmitted almanacs for the operational satellites remained those for July 6, 1983. Moreover, the co-ordinate data in the first

half-minutes were frozen at the values for 1324 and 1327 GMT on that date.[28]

When Cosmos 1333 became unfit for use in its navigation role, it should have been removed from active service by command from ground control. It is still transmitting as of mid-1988 and one must conclude that it has not been switched off because it is technically impossible to do so. This must be a source of embarrassment since it is still routinely included in the navigation messages of the operational satellites in the constellation.

As time progressed it was observed that Cosmos 1333's on-board clock was drifting out of synchronism with Moscow Standard Time, at a rate of 13 seconds per day by 1986 when it was some eight hours "slow". As of April, 1986, Cosmos 1333 was still transmitting a complete message but, by the beginning of July of that year, all data had disappeared leaving only incorrect time and empty data blocks. This situation has continued ever since.[29]

At the start of 1984, Cosmos 1428 had already been in service for one year and, in February, it was replaced by Cosmos 1535. Three months later, Cosmos 1550 was launched into the same plane but was never operational. It never appeared in the almanacs in the second half-minutes of the navigation messages of the operational satellites and no transmissions from it were identified by the Kettering Group.

Cosmos 1598 became the operational satellite following its launch in the fall of 1984. It would seem that Cosmos 1704, launched 14 months later, should have replaced Cosmos 1598. However, with the exception of signals received on two occasions at Bude, England, during the afternoon of November 29, 1985—the day following its launch—nothing more was heard from Cosmos 1704 and it never appeared in the almanacs in the second half-minutes of the navigation messages of the operational satellites. Cosmos 1958 remained as the operational satellite in this plane until it was replaced by Cosmos 1808 in December, 1986.

Cosmos 1535 was reactivated with the temporary identity number 8 at the end of 1984 to provide additional coverage following the failure of Cosmos 1448 in plane 1. It was also observed to be active, with that identity number, at the end of 1985, following the launch of Cosmos 1709 into plane 2 and it may have been reactivated to provide additional coverage during the transition period between Cosmos 1610 and Cosmos 1709.

PLANE 4 (149.970 MHZ)

This appears to have been the healthiest plane of all. Cosmos 1459, launched in May, 1983, was not replaced by Cosmos 1605 until October, 1984. More than two years later, Cosmos 1605 was replaced by Cosmos 1802, which was still active in mid-1988 after more than two and one half years of operation.

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[28] Daly, P. and G. E. Perry, *Space Communication and Broadcasting*, 1986, p. 51–61.
[29] Daly, P., and G. E. Perry, *Space Communication and Broadcasting*, 1987, pp.379–384.

PLANE 5 (150.030 MHZ)

Cosmos 1464, also launched in May, 1985, was replaced after 13 months by Cosmos 1577. Nineteen months later Cosmos 1577 was replaced by Cosmos 1821. This was relatively short-lived, being replaced by Cosmos 1864 after less than four months. Cosmos 1864 was still operational in mid-1988, one year later.

Cosmos 1464 was reactivated with the temporary identity number 9 at the end of 1984 to provide additional coverage, together with Cosmos 1535 in plane 3, following the failure of Cosmos 1448 in plane 1.

PLANE 6 (149.940 MHZ)

Cosmos 1513 had been in orbit for less than one month at the start of 1984 and was not replaced by Cosmos 1634 until March, 1985. Cosmos 1759 replaced Cosmos 1634 in June, 1986. Cosmos 1759 was replaced by Cosmos 1891 in October, 1987. Cosmos 1634 was reactivated with identity number 6 for short periods in July, 1986, and May, 1987, when Cosmos 1759 was turned off.

It will be seen that, in this particular plane, the operational life of a military navigation satellite is of the order of 15 months.

Table 56 shows the replacement sequence of the Cosmos satellites in the military navigation constellation in their respective planes and table 57 shows the right ascensions of the ascending nodes for Cosmos 1333 and the operational satellites in the constellation as of January 1, 1988.

Minor Military Missions

Small payloads for missions which have come to be dubbed "minor military" continued to be launched by the C-1 from both Kapustin Yar and Plesetsk from 1984-1987. Kapustin Yar was used once in each year, with the exception of 1986, to launch into the 50.7° inclination, not directly attainable from Plesetsk.

Table 58 lists these launches separately for each site and sub-divided by orbital characteristics.

Although no definite constellations exist within these minor missions and no specific mission has been positively identified, it will be seen that the orbital characteristics fall into certain well-defined sub-sets.

The 1985 and 1987 flights from Kapustin Yar continued the series of flights launched twice in each of the years 1982 and 1983. Although the orbital period does not differ greatly from the 65.8° flights with 94.5 minute periods launch from Plesetsk, their orbits are markedly more eccentric.

The orbit of the other Kapustin Yar flight resembles to some extent that of Cosmos 1463, launched from Plesetsk in 1983 with an 82.9° inclination.

One of the two flights at 74.0° inclination from Plesetsk has orbital parameters similar to two launches in 1982 and 1983 but the orbit of Cosmos 1868, although having the same orbital period, is very much more eccentric.

TABLE 56.—REPLACEMENT SEQUENCE OF THIRD GENERATION COSMOS MILITARY NAVIGATION SATELLITES: 1984–1987

	1	2	3	4	5
	1448	1386	1428	1459	1464[9]	1513
1984		1531			
			1535[8]		
			(1550)		
					1577
			1598		
				1605	
		1610			
1985	1627				
					1634
			(1704)		
		1709			
1986					1725
	1745				
					1759
				1802	
			1808		
1987					1821
					1864
					1891
		1904			

Notes:
1. Orbital planes are separated by 30° in right ascension of the ascending node.
2. Cosmos numbers immediately below the double line at the top of the table indicate the operational status as of Dec. 31, 1984.
3. Numbers in brackets following the Cosmos designation indicate the identity number assumed after replacement.
4. Certain equipment onboard Cosmos 1333, #7 in plane 3, failed early in July 1983 causing loss of ground-control. Consequently it was still transmitting inaccurate time information at the end of 1987.
5. Cosmos 1550 and Cosmos 1704 were never operational.
6. Table prepared for the Congressional Research Service by G. E. Perry.

TABLE 57.—RIGHT ASCENSIONS OF ASCENDING NODES OF OPERATIONAL COSMOS MILITARY NAVIGATION SATELLITES AS OF JAN 10, 1988

Plane	1	2	3	4	5	6
Cosmos	1745	1904	1808	1802	1864	1891
R.A.	29.7	59.4	89.7	120.0	150.3	180.6

Notes:
1. Planes 1 through 6 are nominally separated by 30° in right ascension of the ascending node, R.A.
2. R.A., is given in degrees.
3. The R.A. of Cosmos 1333, with identity number 7, in plane 3 at this time was 93.6°.
4. Table prepared for the Congressional Research Service by G. E. Perry.

Cosmos 1902, launched at the end of 1987, has the lower orbit characteristic of Cosmos 1502 in 1983, which matched that of Cosmos 1418 at the 50.7° from Kapustin Yar in 1982.

The largest of the sub-sets contains those satellites with near-circular orbits of 94.5 minute orbital period at 65.8° inclination. It is tempting to assume that these perform identical missions but that is not supported by evidence that only two of the six shed fragments at intervals during their missions. As of mid-1988, Cosmos 1601 had produced 28 fragments at intervals and Cosmos 1662 had produced 27. The only other satellite to exhibit such behaviour was Cosmos 1776, at 74.0° inclination, which had produced 20. Analysis

by Nicholas Johnson indicated that the majority of these fragments appeared during the latter part of 1986.[30]

TABLE 58.—MINOR MILITARY COSMOS SATELLITE LAUNCHES FROM KAPUSTIN YAR: 1984–1987

Cosmos number	designator	Launch date	Apogee	Perigee	Inclination	Orbital period
1688	85–89A	10/2/85	548	347	50.7	93.5
1815	87–07A	1/22/87	550	345	50.7	93.5
1578	84–68A	6/28/84	1643	295	50.7	104.5

MINOR MILITARY COSMOS SATELLITE LAUNCHES FROM PLESETSK: 1984–1987

1902	87–103A	12/15/87	411	368	65.8	92.4
1534	84–07A	1/26/84	516	468	65.8	94.5
1601	84–104A	9/27/84	515	475	65.8	94.5
1615	84–127A	12/20/84	500	440	65.8	94.0
1631	85–18A	2/27/85	512	472	65.9	94.5
1662	85–50A	6/19/85	513	476	65.8	94.5
1788	86–83A	10/27/86	517	468	65.8	94.5
1776	86–67A	9/3/86	516	474	74.0	94.5
1868	87–61A	7/14/87	709	284	74.0	94.6

Notes:
1. All satellites were launched by the C–1.
2. Apogee and perigee heights in kilometers, inclination in degrees and orbital period in minutes.
3. Orbital data, which may differ from that given in the Master Log, has been computed from two line orbital element sets provided by NASA's Goddard Space Flight Center.
4. As of mid-1988, 28, 27 and 20 fragments respectively had been released from Cosmos 1601, Cosmos 1662 and Cosmos 1776.
5. Table prepared for the Congressional Research Service by G. E. Perry.

Space Weapons

For many years the Soviet Union resolutely maintained that there was no military component to their space program. In recent years they have modified their stance and referred to certain military programs beyond those implied in the phrase "national technical means" which had been used in connection with negotiation and verification of arms control agreements.

In addition to the reference to RORSATs at the Pugwash Conference, TASS reported in 1985 that:

> The Soviet Union is carrying out research, including military research, but it is not aimed at developing attack space weapons but is related to the improvement of early warning, surveillance, communications, and navigational space systems.[31]

A few weeks earlier, Colonel General Nikolai Chervov revealed during arms control talks in Geneva, Switzerland, that the Soviet Union had successfully tested an ASAT system, but described it as a direct ascent ASAT, the testing of which began in the late 1970s and continued against "imaginary points outside the atmosphere" until 1982.[32] He disputed U.S. assertions about tests of a co-orbital ASAT (see below) against Soviet satellites.

[30] Johnson, N. L. *The Soviet Year in Space 1986.* Teledyne Brown Engineering, Colorado Springs, CO., 1987. p. 49.
[31] *TASS,* June 15, 1985.
[32] *Frankfurter Rundschau,* Frankfurt, Main, West Germany, May 30, 1985, p. 1.

Later in 1985, the Soviets admitted conducting their own Strategic Defense Initiative (SDI) laboratory research.[33]

CO-ORBITAL ASAT

The Soviet Union conducted 20 tests of its co-orbital ASAT in the years between 1968 and 1982 with varying degrees of success. Initially, radar sensors were used by the interceptors to detect the target satellites but, beginning with Cosmos 886 in December 1976, some tests were conducted using an unjammable infra-red optical sensor. Remarkably, not one of the six tests using the supposedly improved sensor is believed to have been successful. A table detailing all known tests is provided in chapter 1 (table 5).

At the same time they submitted a draft treaty to ban space weapons for consideration by the United Nations in August, 1983, the Soviet Union unilaterally declared a moratorium on the testing of ASATs. This was timed to exert pressure on the United States not to proceed with the testing of the miniature homing vehicle (MHV) designed for launch from an F-15. As a result of this there have been no further tests of the Soviet co-orbital ASAT since the apparently unsuccessful test in mid-1982.

On September 5, 1985, eight days before the successful U.S. test of the MHV against an object in space, the Soviet Union warned that if the United States were to conduct such a test, it would consider itself released from its unilateral commitment not to deploy ASAT weapons in space.[34]

Following the test, which resulted in the destruction of the aged U.S. Air Force P78-1 Solwind satellite, General Secretary Mikhail Gorbachev was reported to have said that the moratorium was null and void.[35] However, in December 1985, the U.S. Congress banned U.S. ASAT tests against objects in space until October 1986, and subsequently extended the ban through October 1988.[36]

Although there have been no tests of the Soviet co-orbital ASAT since June, 1982, the F-1 launch vehicle has been flown, on average, five times a year from 1984 through 1987, in support of the EORSAT and RORSAT programs. In 1984, it was reported that additional ASAT storage facilities had been provided at Tyuratam.[37]

Some details of the Tyuratam facility and estimates of its capability and ASAT performance were given in the U.S. Department of Defense pamphlet *The Soviet Space Challenge.*[38] In describing "the world's only currently operational ASAT system" it states,

> Using a radar sensor and a pellet-type warhead, the interceptor can attack all current low-altitude satellites. . . . The interceptor can reach targets orbiting at an altitude of more than 5,000 kilometers, but it probably is intended for high priority satellites at lower altitudes.

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[33] *Neue Az, Vienna,* Austria, Oct. 19-20, 1985, p. 5.
[34] Radio Moscow. Sept. 5, 1985.
[35] *NHK TV,* Tokyo, Japan, Sept. 17, 1985.
[36] For a discussion of U.S. ASAT Activities, see: U.S. Library of Congress. Congressional Research Service. ASATs: Antisatellite Weapon Systems. Issue Brief No. IB85176, by Marcia S. Smith. 15 p. (continually updated).
[37] *Aerospace Daily,* Dec. 27, 1984, p. 281.
[38] U.S. Dept. of Defense. *The Soviet Space Challenge.* Washington, 1987. p. 41.

The antisatellite interceptor is launched from Tyuratam where two launch pads and storage space for many interceptors and launch vehicles are available. Several interceptors could be launched each day from each of the pads.

Soviet references to their ASAT include an assertion that their ASAT tests had been halted following the 1983 unilateral moratorium[39] and the director of the Space Research Institute in Moscow, Dr. Roald Sagdeyev, confirmed during a press conference condemning the U.S. Strategic Defense Initiative that the Soviet Union had tested a co-orbital ASAT between 1968 and 1982.[40]

DIRECTED ENERGY WEAPONS

The U.S. Department of Defense annual Soviet Military Power publications have provided details on a variety of directed energy weapons including lasers, particle beams and high power microwaves, which it asserts are under development as ASAT weapons. These are summarized in *The Soviet Space Challenge* pamphlet.[41]

Laser Weapons

DOD estimates that the Soviet's laser program is "larger than U.S. efforts and involves over 10,000 scientists and engineers as well as more than a half-dozen major R&D facilities and test ranges." [42] Sary Shagan was pinpointed as the location for much of the research. It was estimated that the facility housed several lasers for air defense and two lasers which were probably capable of damaging satellites in orbit. The report stated that one of these could be used in feasibility testing for ABM applications. The annual cost of the laser program was estimated to be in the region of $1 billion.[43]

Soviet scientists had "achieved impressive output power" from gas-dynamic, electric discharge and chemical lasers and were "possibly exploring the potential of visible and very-short-wave-length lasers." They were said to be investigating excimer, free-electron and x-ray lasers, and also developing argon-ion lasers.[44]

In 1986 it was reported that U.S. intelligence had detected two large facilities under construction on mountain tops near Dushanbe, to the north of the border between the Soviet Union and Afghanistan.[45] In the following year the same magazine published pictures taken by the French SPOT remote sensing satellite which suggested that the complex consisted of four domed lasers in a diamond formation.[46]

The production of a 1.2 meter diameter segmented mirror in 1978 for an astrophysical telescope which had been claimed to be a prototype for a 25 meter diameter mirror was advanced as evidence for the development of optical systems necessary for long-range space-based laser weapon systems[47] and Salyut cosmonauts were

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[39] *TASS*, Sept. 17, 1985.
[40] *Frankfurter Rundschau*, Frankfurt, Main, West Germany, Dec. 5, 1985, p. 8.
[41] U.S. Dept. of Defense. *The Soviet Space Challenge*. Washington, 1987. p. 15–17.
[42] *op. cit.*, p. 15.
[43] *Ibid.*
[44] *Ibid.*
[45] *Aviation Week and Space Technology*, Sept. 15, 1986, p. 21.
[46] *Aviation Week and Space Technology*, Oct. 26, 1987, p. 26–27.
[47] Ibid., *The Soviet Space Challenge*.

reported to be conducting laser-pointing and tracking experiments.[48]

A second reference to cosmonaut participation claimed that Romanenko and Laveikin onboard the Mir orbital station in 1987 had "used a laser beam to target and track a Soviet-launched intercontinental ballistic missile." [49] This was promptly refuted.[50]

Senior Soviet spokesman Gennadiy Gerasimov dismissed as "slander" Western media claims that the Soviet Union had installed "strategic defense lasers", including one at Sary Shagan in Kazakhstan, and had used them to put three American satellites out of action. Gerasimov said that the Soviet Union had no laser weapons and that the "experimental laser device" at Sary Shagan was used for "surveying space and tracking targets in space." [51]

Cosmos 1767

The J-1 launch of Cosmos 1767, considered to be an engineering test,[52] was thought by some Western analysts to have been testing a chemical laser weapon.[53] This suggestion brought a categorical denial from the Soviets. Vladislav Drobkov, writing in *Pravda*, said that according to "competent Soviet organizations, . . . there is no connection whatsoever (and there can be none) between the launching of the Cosmos 1767 satellite and the testing of anti-satellite weapons." [54]

Particle Beam Weapons

DOD claims that the Soviets had been "exploring the feasibility of using particle beams for a space-based weapon system" since the late 1960s and might be in a position to test a prototype intended to disrupt the electronics of satellites in the 1990s. An operational system to destroy satellites could follow but the destruction of missile boosters or warheads was further down the line.[55]

Radio-Frequency Weapons

Research into the use of high-power microwave signals having the potential to interfere with or destroy critical electronic components of satellites or ballistic missile warheads could lead to the deployment of a ground-based weapon for use against satellites in the 1990s, according to DOD.[56]

THE KRASNOYARSK PHASED ARRAY RADAR

U.S. concern was expressed in 1985 over a new large phased array radar discovered to be under construction at Krasnoyarsk (57°N, 93°E) which, if used for ballistic missile warning, would, by virtue of its location, violate the ABM Treaty. The Soviet Union declared it as a space surveillance radar[57] but a visit by a U.S. Con-

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[48] *Aviation Week and Space Technology*, Jan. 28, 1985, p. 27.
[49] *Wall Street Journal*, July 15, 1987, editorial.
[50] *Defense Daily*, July 17, 1987, p. 90-91.
[51] *TASS*, Oct. 30, 1986?
[52] *Soviet Space Programs: 1981-87*, Part 1. Washington, U.S. Govt. Print. Off., May, 1988. p. 244-245.
[53] *Defense News*, Aug. 25, 1986, p. 2.
[54] Drobkov, V., *Pravda*, Sept. 6, 1986.
[55] *The Soviet Space Challenge*, op. cit., p. 16-17.
[56] *op. cit.*, p. 17.
[57] Radio Moscow. July 10, 1985.

gressional delegation to the site in September 1987, produced no unambiguous assessment of its purpose when completed. Following that visit the Soviet Union declared a one year's moratorium on further work at the site.[58]

[58] Radio Moscow. Dec. 3, 1987.

SECTION TWO: ADMINISTRATION AND RESOURCE BURDEN OF THE SOVIET SPACE PROGRAM

CHAPTER 1—ADMINISTRATION OF THE SOVIET SPACE PROGRAM UNDER GORBACHEV [1]

INTRODUCTION

The Soviet Union traditionally has veiled its entire space program in secrecy. Therefore, very little has been known in the West about the organization of either the military or civilian programs. Since Mikhail Gorbachev's rise to the leadership, the Soviet Union has made some of its space activities more accessible to Western observers. To date this greater openness has not extended to questions of structure and administration of the program. Therefore, any analysis remains somewhat speculative. This chapter is pieced together from bits of information provided in Soviet and Western open sources and from "educated speculation" by Western experts.[2]

This chapter focuses on recent changes in the structure of the Soviet space program, as well as on the impact of Gorbachev's overall strategy on the program. The first section looks at elements of continuity and change in Gorbachev's approach to space. The second section looks at changes in the actors involved in top level decisionmaking in space. The final section examines the changes in the working level management of the space program, its civilian and military components. To date there has been more continuity than change in the Soviet space program under Gorbachev. But more far-reaching changes have been proposed by the leadership. With Soviet policy in a rare state of flux, further restructuring of the space program seems very possible.

GORBACHEV'S IMPACT ON THE SOVIET SPACE ORGANIZATION

CONTINUITY OF COMMITMENT UNDER GORBACHEV

The Soviet space program is influenced by Mikhail Gorbachev's campaign to restructure the Soviet Union. Gorbachev appears to have established as his highest priority the restructuring and modernization of the Soviet economy. He has depicted this task first and foremost as a national security requirement without which the Soviet Union will find it difficult to keep pace with the West and ensure its place as a superpower in the 21st Century.[3] The alternative, from Gorbachev's perspective, is prolonged stagnation. To achieve his goals, Gorbachev will have to institute major economic

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[1] This section updates a chapter appearing in the earlier volume: Soviet Space Programs, 1976–1980.

[2] See also U.S. Congress. Office of Technology Assessment. U.S.-Soviet Cooperation in Space: A Technical Memorandum. Washington, July 1985. 113 p.

[3] Gorbachev, Mikhail S. Political Report of the CPSU Central Committee to the 27th CPSU Congress. Feb. 25, 1986. Carried in Pravda, Feb. 26, 1986. p. 2–10. (FBIS Daily Report: Soviet Union, Feb. 26, 1986. p. O1–42.)

reforms and reallocate resources among claimants. Any major transfer of resources within the economy is likely to be at least in part at the expense of military allocations.[4]

Although the Soviet space program is closely tied to the military, few observers expect it to suffer serious cutbacks under Gorbachev's leadership. On the contrary, all evidence suggests that Gorbachev is very committed to the program.[5] Not only has there been no slackening of the pace of Soviet space activity, but the program seems to fit well with Gorbachev's priorities. Like other Soviet leaders before him, Gorbachev probably recognizes the military benefits and applications of space research. He is also likely to appreciate, even more than previous Soviet leaders, the domestic and international political benefits of the space program. Gorbachev is credited with being a master at public relations. The space program generates domestic public support and pride in an endeavor clearly associated with the government. At the same time, space successes also enhance the Soviet Union's international prestige, as a leader in the most advanced fields of science and technology. The highly-visible involvement of other countries in joint space ventures probably generates goodwill abroad. The continued inclusion of foreign cosmonauts on Soviet space flights provides the image of a Soviet Union willing to share the "glory" and tangible benefits of space exploration. If anything, the emphasis on international cooperation has been stepped up under Gorbachev. The Soviet leadership may also be looking to international space cooperation as a way of breaking out of international isolation in the scientific and technological field, to use an area in which the Soviets themselves have a lot to offer to open the door to greater access to Western technology.

Most importantly, Gorbachev is likely to see in the Soviet space effort the kind of successful high technology program that can stimulate and provide a model for other sectors of the Soviet economy, noted for their glaring inefficiencies and chronic shortfalls. His strong commitment to the space program might reassure the military, at a time when they are uncertain about the future flow of resources to defense in general. Any cutbacks in Soviet military spending, Western experts believe, would be justified in terms of short term sacrifices in military hardware for long-term benefits in more sophisticated advanced weaponry. Continued allocations to military space programs would seem to support that argument.

CHANGES IN APPROACH

Despite the continuity of commitment, there have been and are likely to be changes in the structure of the space program in conjunction with Gorbachev's reforms. Even if the space program were not directly targeted for change, it would be affected by the planned changes in Communist Party and government responsibil-

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[4] For a discussion of trade-offs between military and economic allocations, see: Hardt, John P. Soviet Economic Constraints on Defense to the Year 2000. Appears as appendix in: Stanley, Timothy W. Western and Eastern Economic Constraints on Defense. (Atlantic Council Occasional Paper, Fall 1986.)

[5] Soviet leader Gorbachev's commitment to space was underlined in his speech at the Baykonur Cosmodrome on May 13, 1987. Pravda, May 14, 1987. p. 1-2. (FBIS Daily Report: Soviet Union, May 14, 1987, p. R1-8.)

ities. But the program may be targeted for reform. Despite its level of accomplishments, the Soviet space program has not proven itself immune to criticism or above calls for restructuring.

Roald Sagdeyev, the Director of the Soviet Space Research Institute and a leading figures in the Soviet space program, as well as a reported close advisor to Gorbachev, has criticized Soviet science and space policy in a number of articles and interviews. According to Sagdeyev, the Soviet Union is contributing too little to the world's scientific knowledge and has only modest achievements, despite one of the world's largest pools of scientists. He contrasts French, German, and American science which are "vibrant with new ideas" with Soviet science which he calls "stultifying." While he concedes that the Soviet Union has had some significant space achievements, he views these as rare flashes of brilliance. He argues that even the recent emphasis on "perestroika" has had little impact on Soviet science and space policy.

Sagdeyev identifies some key shortcomings of the Soviet system. He notes that barriers have been set up, compartmentalizing the different institutions and individuals engaged in research and development. The mobility and interaction of scientists which are taken for granted in other countries are virtually nonexistent in the Soviet Union. He sees the fact that so much research is classified because of supposed military importance as a major obstacle to Soviet scientific progress. Soviet scientists have little access to computers, making their challenge like that of fighting a modern war with crossbows, in Sagdeyev's view. Even the major space research institutes which get preferential treatment suffer from this shortcoming. He sees the neglect of basic science in favor of applied science, as a policy with serious negative implications for future Soviet capabilities.

Sagdeyev believes that scientists have too little influence over science related decisions. Politicians make the key decisions on political motives, with little understanding of scientific trends and realities. This results in misguided policies such as what he views as an overemphasis on piloted space flight at the expense of automated efforts that produce more scientific results at lower cost (a mistake he sees as being duplicated by the United States).[6] Many of the changes being proposed by Gorbachev in the fields of science and space policy suggest that he is aware of the weakness discussed by Sagdeyev. Gorbachev is seeking to revamp the planning and management system. He wants to centralize the strategic planning process and overall control by the Communist Party leadership. At the same time, he wants to decentralize management of the institutions directly involved in research and development, increasing their local autonomy and initiative.[7] To do this he is trying to reduce the ability of the Party apparatus to interfere in their day-to-day work and also to streamline and decrease the role of the government's ministerial bureaucracies. Recently, Gorbachev has proposed the creation of new institutions in order to break down

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[6] Sagdeyev, Roald Z. Science and Perestroika: A Way to Go. Issues in Science and Technology, Summer 1988. p. 43.

[7] Soviet Science under Gorbachev. A meeting report on a presentation by John Thomas given at the Kennan Institute of the Wilson Center. Oct. 15, 1986.

the compartmentalism that has plagued space and other scientific programs. At the 19th Communist Party Conference, he called for the creation of "intersectoral scientific-technological complexes, engineering centers and ad hoc collectives" for accomplishing specific tasks.[8] A new space agency "Glavkosmos" (discussed later) has been created, presumably to upgrade civilian programs and pursue international commercial opportunities for what remains a military-dominated program.

Gorbachev's policy of "glasnost" or openness is also geared to breaking down compartmentalization and unleashing creativity in science and technology. He argues that a changed climate, allowing for a more open exchange of ideas and information, is essential to innovation and technological progress. He is calling for more unrestricted competition of scientific ideas within the whole Soviet system.[9] But as Sagdeyev has pointed out, these proposals have yet to be acted on and are facing stiff resistance among conservatives in the leadership, the mass bureaucracy, and even the public at large.

High Level Decisionmaking and Coordination

The *Communist Party* continues to assert its leadership over the space program, as in all areas of Soviet policy. Top level decisions on space are made in the Politburo. Control over implementation of the decisions is the responsibility of the appropriate departments in the Central Committee. If political reforms pressed by Soviet leader Gorbachev are implemented, this Party control is likely to be strengthened at the macro level, although Party meddling in the implementation of space decisions may be reduced. It is not clear how the top Party bodies will divide their responsibilities with a new State President and revamped Supreme Soviet, if these new institutions are established as proposed by Gorbachev.[10]

The *Politburo,* in its capacity as the highest policy-making body in the Soviet Union, continues to be responsible for establishing goals and priorities, setting up the organizational framework and funding of the space program. Final responsibility on space matters within the Politburo rests with Party General Secretary Gorbachev and the other Politburo members on the Defense Council—the top level coordinating body on national security issues. Gorbachev's level of personal involvement in space decisions is not known but, in view of his strong interest in the advancement of Soviet high technology, it is likely to be considerable.

As the Politburo member and Party Secretary in charge of overseeing defense industry, Lev N. Zaykov may be directly responsible for the space program.[11] This would correspond with past Soviet practice.

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[8] CPSU Central Committee Report delivered by Mikhail S. Gorbachev at the 19th All-Union Conference, June 28, 1988. (FBIS Daily Report: Soviet Union, June 29, 1988, Supplement. p. 8–10.)

[9] Ibid., p. 9.

[10] CPSU Central Committee Report delivered by Mikhail S. Gorbachev at the 19th All-Union Conference, June 28, 1988. (FBIS Daily Report: Soviet Union, June 29, 1988, Supplement, p. 19–20.)

[11] U.S. Central Intelligence Agency. Communist Party of the Soviet Union Politburo and Secretariat. Oct. 1987. (LDA–87–14838)

The *Central Committee* is divided into departments, which for the most part parallel the government structure at the ministry level. These departments have oversight of the corresponding ministries in the government. The departments also provide information to the Politburo.

It is difficult to name all the Central Committee departments most closely involved with the space program, as all have not been fully identified. The departments handling defense industries (headed by Oleg S. Belyakov) and science and educational institutions (headed by Valentin A. Grigoryev) probably have a key role in the oversight of the space program.[12] From the Central Committee down, there is a vast network of Party organizations which assure Communist Party control over the space program at all levels. Basic Party units are present at research institutions, in the Soviet Academy of Sciences and its branches, in the relevant military sections and within the industries doing space work. Party involvement at lower level, however, may be curtailed if Gorbachev's political reforms are implemented because he has identified Party and government intrusion as a hindrance to success.

The *Council of Ministers* is the highest body of the Soviet government. In practice the Council of Ministers is selected by and responsible directly to the Central Committee of the Communist Party. The Chairman of the Council of Ministers is Nikolay I. Ryzhkov.

Directly under the Council of Ministers are the ministries, state committees, and other bodies which carry on the day-to-day tasks of Soviet government. The Soviet Academy of Sciences also falls under the supervision of the Council of Ministers. Below the ministries are the industrial branches and the institutions which they oversee.

Central Committee policy guidelines on space probably pass directly to the Council of Ministers. The passing of directives from the Central Committee of the Communist Party to the Council of Ministers is simplified by the fact that members of the Council of Ministers and the heads of the subordinate ministries, state committees and other agencies all simultaneously hold high Party offices. Nikolay Ryzhkov and four other current members of the Council are full or candidate members of the Politburo.

Members of the Council of Ministers who may play a significant role in the space organization, are Dimitriy T. Yazov (Minister of Defense), Yuriy D. Maslyukov (Chairman of the Military Industrial Commission), Boris L. Tolstykh (Chairman of the State Committee on Science and Technology), Nikolay V. Talyzin (Chairman of the State Planning Committee), Vyacheslav V. Bakhirev (Minister of Machine Building), Lev A. Voronin (Chairman of the State Committee for Material and Technical Supply), Pavel V. Finogenov (Minister of Defense Industry) and Mikhail S. Shkabardnya (Minister of Instrument Making, Automation Equipment and Control Systems).[13] Others who may be involved include Apollon S. Systsov

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[12] U.S. Central Intelligence Agency. Soviet Communist Party Central Committee Executive and Administrative Apparatus. Nov. 1987. (LDA 87-14611).

[13] Kraus, Herwig and Alexander Rahr. The Government of the U.S.S.R. Radio Liberty Research Bulletin, May 5, 1987. (RL Supplement 3/87).

(Minister of Aviation Industry) and Gennadiy A. Yagodin (Minister of Higher and Secondary Specialized Education).[14]

Attached to the Council of Ministers, according to one source, is the Coordinating Council for Space Research which has previously been headed by Sergey Korolov and other "Chief Designers" of the space program. The identity of these individuals are generally kept secret until after their death. Its duties are reportedly to coordinate research and development, endorsing lines of production and proposing funding. This organization has not been mentioned in other recent sources.[15]

The *Military Industrial Commission (VPK)* is reported to be responsible for actual management of the military space program and coordinating all of the elements involved in developing and producing space systems.[16] According to one source, the VPK is the main high level link between the Party, government, and military complex.[17]

The *State Committee on Science and Technology* is the highest government coordinating body for scientific work, at least in the civilian sector. There are differences of opinion among Western analysts regarding the role the committee plays in the space organization. It is generally thought to have a significant role, although its position may be limited to that of coordinating some of the associated research and development activity contributing to the space program.[18] The State Committee is responsible for coordinating Soviet research and development (primarily in the civilian sector), establishing priorities, and introducing new technology into the industrial areas. Furthermore, the committee oversees the numerous research institutes and laboratories now under the industrial ministries. It includes in its ranks a preponderance of officials from the defense industry sector, suggesting that the defense establishment has significant influence over the civilian scientific and technological establishment.

The *State Planning Committee* (GOSPLAN) is responsible for planning scientific, technological, and economic activities in the Soviet Union, as well as exercising budgetary control. It has an input into most Soviet undertakings, especially those such as the space program, in which numerous organizations and sectors of the economy are involved. The Committee is also responsible for overseeing plan fulfillment. One of its most important duties is to participate in formulating the overall short- and long-term plans of the Soviet Union, such as the Five Year Plan. Integration of the space program with the other national undertakings would seem to require a considerable degree of involvement by the Committee.

Over the years Western experts have been interested in the question of how the roles of all these actors are coordinated. There has been much speculation but no conclusive evidence that there is a

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[14] Yevsikov, Victor. Re-entry Technology and the Soviet Space Program; Some Personal Observations. Falls Church, Delphic Associates, Dec. 1982. p. 14. The author identifies many of these same ministries and committees as playing a role.

[15] Ibid., p. 17.

[16] U.S. Defense Intelligence Agency. Soviet Military Space Doctrine, Aug. 1, 1984. p. 26.

[17] Thomas, John R. Militarization of the Soviet Academy of Sciences. Survey, v. 29, Spring 1985. p. 38.

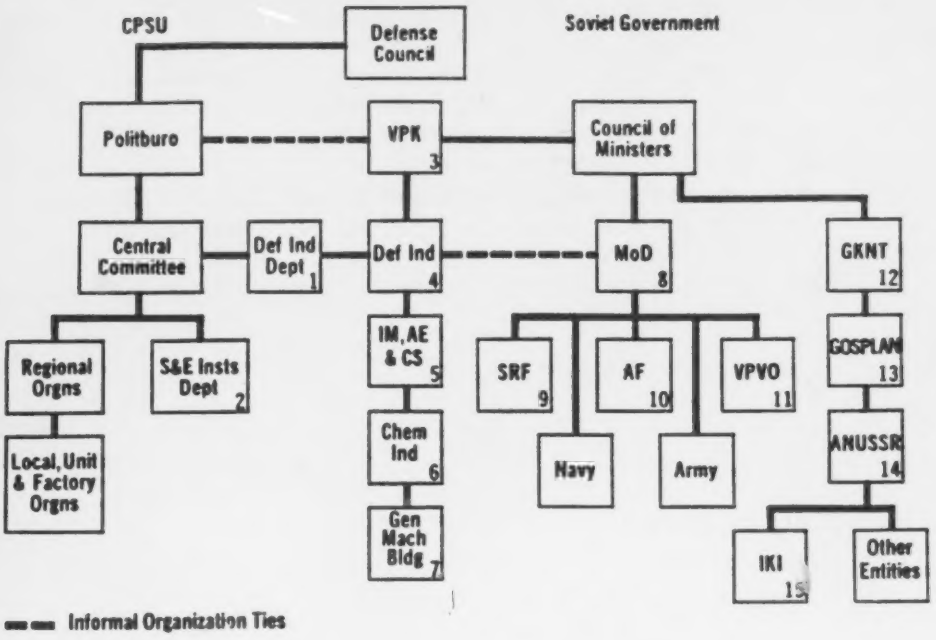
[18] Smolders, Peter L. Soviets in Space: The Story of the Salyut and the Soviet Approach to Present and Future Space Travel. Guildford, Lutterworth Press, 1973. p. 29.

single coordinating agency or mechanism. Many analysts believe that the Soviet Union has no space agency which approximates the U.S. National Aeronautic and Space Administration. In place of such an organization, they perceive an elaborate system of coordination among participating institutions on an informal basis. When stumbling blocks and jurisdictional bottlenecks develop, as those that plague much of the civilian sector, high Soviet officials can and do intervene. Unlike systems where a strict hierarchical chain of command operates upward and downward, top Soviet leaders can deal directly with those responsible for programs at any level, even individual scientists at local research institutes.[19]

Coordination is also facilitated by the multiple responsibilities assigned to leading individuals. Where there is no clear link between organizations involved in the same program, a link may often be found in the person of their leadership.

[19] Yevsikov, op. cit., p. 16.

Figure 27.—Soviet Military Space Organization



1. Central Committee Defense Industries Dept.
2. Central Committee Scientific and Educational Institutions Dept.
3. Military Industrial Commission.
4. Ministry of Defense Industries.
5. Ministry of Instrument Making, Automation Equipment and Control Systems.
6. Ministry of the Chemical Industry.
7. Ministry of General Machine Building.
8. Ministry of Defense.
9. Strategic Rocket Forces.
10. Air Force.
11. Air Defense Forces.
12. State Committee for Science and Technology.
13. State Committee for Planning.
14. USSR Academy of Sciences.
15. Institute for Space Research.

Source: U.S. Defense Intelligence Agency. Soviet Military Space Doctrine. Washington, Aug. 1, 1984 (DDB–1400–1684). p. 27.

Operational Management of the Space Program

Most Western experts agree that the military dominates the Soviet space program at the operational level. One observer has gone so far as to say "it's solely military from beginning to end with small civilian appendages."[20]

This does not mean the military has ultimate power over the program. In fact the military establishment itself is firmly controlled by the Communist Party, not only from the top but throughout the hierarchy.[21] The Communist Party has always retained ultimate control over the space program, as indicated in the previous section.

At least until Glavkosmos was created in 1985, operational responsibility for the space program, as a whole, seems to have been primarily in the hands of the military. Some Western experts believe that, directly or indirectly, military officers or officials with defense or defense industry backgrounds were in charge of all military and civilian activities.[22] With the establishment of Glavkosmos, some observers believe that the Soviet Union may be moving in the direction of establishing a distinct civilian program or at least more clearly separating the military and civilian components.

Role of the Military

The Defense Ministry which coordinates the military role in the space program has experienced major personnel changes at the top under Gorbachev. It is not yet clear how this might affect the space program. Presumably the new senior officers will be more supportive of Gorbachev's restructuring plans. Unlike the U.S. Defense Department, the Soviet defense establishment consists of military men from top to bottom. Former Defense Minister Dimitriy F. Ustinov was the first and only civilian to occupy the position of defense minister and even he had been associated with military-industrial affairs throughout his career. The Defense Ministry maintains strong influence over the strategic industries which manufacture space systems even though these industrial sectors are under the Defense Industries and other ministries.

Below the Defense Ministry, the General Staff and the Main Political Administration of the armed forces, all have an influence on the space program. The Main Political Administration acts as the party's "watch dog" in the military and is simultaneously a section of the Party Central Committee. At the next level in the military space hierarchy are the relevant operating commands, and the five branches of the military: the Army, Navy, Air Force, Air Defense Command, and the Strategic Rocket Force. The Strategic Rocket Force and the Air Force are the two branches with a direct operational role in the space program.

The *Strategic Rocket Force* is most directly involved in the actual operations of the space program. It conducts all space rocket

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[20] Redden, Jack. The Sky's no Limit for Soviets' Ambitious Space Program. Chicago Tribune, Section 5, Dec. 15, 1985. p. 1.

[21] Soviet Military Policy under Gorbachev. Meeting Report on a Presentation by Condoleezza Rice on May 13, 1987, at the Kennan Institute, Wilson Center.

[22] Linville, Ray P. Space and Soviet Military Planning. Space Policy, v. 2, Aug. 1986. p. 234-239.

launches whether for military or civilian purposes. The Strategic Rocket Force is also thought to operate some tracking stations and tracking ships and may exercise control over the launch facilities. It was established in 1960 and is the elite branch of the Soviet military. The primary mission of the force is to launch strategic nuclear missiles. The size of the force has been estimated at 250,000 men. It is commanded by Army General Yuriy P. Maksimov, who is a member of the Central Committee of the Soviet Communist Party.[23]

The Soviet *Air Force* is responsible for cosmonaut training at Star City (Zvyezdniy Gorodok) near Moscow and for the recovery of spacecraft. The Soviet Air Force, or long-range Air Force as it is sometimes called, is distinct from the Air Defense Command. The Air Force is presently commanded by Marshal of Aviation Aleksander N. Yefimov, also a full member of the Central Committee of the Communist Party.[24]

ROLE OF CIVILIAN INSTITUTIONS

In October 1985, the Soviet Union announced the establishment of a new civilian space agency, identified as the Main Directorate for the Creation and Use of Space Technology for the Economy and for Scientific Research or *Glavkosmos* for short. This has been the biggest organizational change under Gorbachev to date. The Director of the new agency is A. I. Dunayev. In announcing the establishment of the new agency, *Izvestiya* stated that because the use of space technology was of interest to so many government ministries, agencies and scientific organizations, and had acquired such broad scope, it was necessary to create a coordinating agency. Glavkosmos considers proposals for projects, works out long-term plans, and administers programs. It is responsible for the design, construction, and use of spacecraft for scientific research, remote sensing applications, and joint space programs with other countries. It also has reportedly been charged with administering the Interkosmos program.[25] It is not clear whether Glavkosmos comes under the supervision of one of the ministries, as its name "Main Administration. . . ." would normally imply or whether it is an independent agency under the general supervision of the Council of Ministers. The latter is suggested by the fact that Glavkosmos has not been identified with any single ministry but works with several ministries.[26]

Some Western observers who have had first hand experience with Glavkosmos are favorably impressed.[27] It seems to be acting as a high-level body with the power to make program decisions, as a contact between Soviet industries and scientific institutes, as well

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[23] U.S. Central Intelligence Agency. Directorate of Intelligence. USSR Ministry of Defense, Mar. 1988. (LDA 88–10905).

[24] Ibid.

[25] New York Times, Oct. 31, 1985, p. B13.

[26] Shabad, Theodore. Civilian Space Agency Announced by Moscow. New York Times, Oct. 31, 1985.

[27] See Gibson, Melinda. The Selling of the Soviet Space Program. The World and I, Mar. 1987. p. 94.

as the main contact for international cooperation and commercial ventures.[28]

Under the Gorbachev reform program, the Soviets have sought to gain more of an economic return for their space investments.[29] The Soviet government has decided to market its space services abroad. A foreign trade entity, *Licensintorg,* has been tasked with selling launch vehicle services to foreign countries. Licensintorg operates in coordination with Glavkosmos.[30]

Another Soviet organization, *Soyuzkarta,* has responsibility for marketing Soviet remote sensing data abroad. According to reports, foreign governments and businesses have shown considerable interest in this service, even though the Soviets reportedly restrict sales to photographs of the purchasers own national territory.[31]

The Soviet Academy of Science's role in the Soviet space organization has been most visible and highly publicized by the Soviets. Prior to the creation of Glavkosmos, the Soviet Union presented it at various times as the counterpart of the U.S. National Aeronautical and Space Administration, in terms of its space role. Outside observers have agreed that the Academy is one of the institutions playing a role, providing research support, consultation, and acting as spokesman for the program at home and abroad, but have been skeptical of the claims of its central role.

Roald Sagdeyev recently charged that the Academy has evolved from being a center for fundamental research to becoming just another bureaucratic "ministry" with a political rather than a scientific agenda. And in that role it is seen as a weak partner to the real ministries. The research institutes under the Academy are said to have swollen to the point where they are now inefficient bureaucracies with staffs of thousands.[32]

According to one Western analysis, the Academy has been "militarized" and "industrialized" to the point where it is now primarily involved in applied research and military R&D. It is reportedly linked to the military in a number of ways, coordinated through its Section on Applied Problems. Top positions at the Academy are held by people with close ties to the milita . All of the presidents of the Academy since 1945 have reportedly been directly involved in weapons R&D as has Academician Velikhov, the only Vice President for Science and Technology since that post was established in 1977.[33]

Soviet General Secretary Gorbachev has moved to restructure the Academy of Sciences. Under new President Guriy Marchuk, half of the members of its ruling Presidium have been removed because of old age. Their replacements are being chosen through a series of ballots of Academy members, with multiple candidates put forward for each position.[34]

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[28] See: Lenorovitz, Jeffrey M. Soviet Aims Include Expanding International Space Participation and Streamlining Management. Commercial Space, Spring 1986. p. 37–38.

[29] West, Bren. U.S.-Soviet Cooperation in Space. Radio Liberty Research, July 13, 1988. p. 6. (RL 332/88).

[30] Proton Marketing Team Finds U.S. Interest, Opposition. Aviation Week and Space Technology, May 25, 1987. p. 20.

[31] Soviet Firm Sells Sells Satellite Photographs Abroad. Trud, Jan. 20, 1988. p. 4. (FBIS Daily Report: Soviet Union, Jan. 26, 1988, p. 76.)

[32] Sagdeyev, op. cit., p. 10.

[33] Thomas, John R., op. cit., p. 37–38.

[34] Mass Retirement in the Leadership of the Soviet Academy. Science, June 24, 1988. p. 1728.

It remains to be seen whether the changes address the chronic tensions that some analysts see in relations between the Communist Party and the science community. Soviet science has been subjected to Party control without the scientists themselves having been integrated, to any significant degree, into the government decisionmaking process, although individual space scientists have at times had significant decisionmaking influence.

Within the structure of the Academy, several commissions and sections have been directly involved in the space program. It is not clear which of these organizations has been superseded or come under the administration of Glavkosmos.

One source indicates that under the Academy's Presidium is a Council for New Technology which deals with questions of space research and rocket construction.[35]

A major agency of the Academy of Sciences is the Council for International Cooperation in the Studies and Uses of Outer Space (Interkosmos). The Council is the coordinator for all cooperative space ventures with other Communist countries.

The Institute of Space Research, directed by Sagdeyev, is one of the main advanced research centers operated by the Academy. It was reportedly founded in 1965, to coordinate and centralize civilian space programs.

The Commission on the Exploration and Utilization of Space is another space institution under the Academy, reportedly established to develop experiments to be carried out in space, publicize Soviet space achievements, maintain contacts with foreign space organizations, and send scientists to represent the Soviet Union at international space conferences. Another institution apparently under the auspices of the Academy of Sciences is the Commission for the Promotion of Interplanetary Flights. At least one of its important duties seems to be as spokesman and representative internationally for the Soviet space program. A number of other departments and institutes of the Academy contribute to the space program.

The Soviet Academy of Sciences allegedly also operates some of the space tracking stations within the Soviet Union and 10 of the tracking ships operating around the globe. Other space communications ships are operated by the Navy and the Strategic Rocket Force. The Coordination and Computing Center, which analyzes communications received from space, is also reportedly under the Academy.

Universities in the Soviet Union are thought to have little input to research and development. Their work does not seem to be integrated with the research performed at the Academy and elsewhere. This compartmentalization inhibits the exchange of technological information between the universities and the space organization and among the universities themselves. The universities may constitute a large untapped resource for the Soviet space program which Gorbachev may seek to better integrate into space research.

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[35] Yevsikov, op. cit., p. 26.

CHAPTER 2—RESOURCE BURDEN OF THE SOVIET SPACE PROGRAM [1]

HIGHLIGHTS

MILITARY SPACE HAS HAD A HIGH PRIORITY SINCE KHRUSHCHEV

Resource commitments to the Soviet Space Program, representing the high priority of the Brezhnev period, will likely continue into the 1990s. Since the success of the Sputnik in the late 1950s, Soviet space programs have continuously had a high priority, as an important means of gaining strategic advantage and international prestige. Military space development designed to provide strategic advantage, dominated the Soviet space program since Khrushchev upgraded strategic military programs following the Cuban Missile Crisis in 1962; civilian space continued to be important for international prestige and technological advantage. During the Brezhnev years, space and related military programs rose in terms of absolute and relative spending and economic burden.

SOVIET SPACE SPENDING IS HIGH, BUT HOW HIGH IS DIFFICULT TO DOCUMENT

All estimates of space spending in rubles or dollars are rough orders of magnitude due to Soviet secrecy, the lack of reliable ruble value measures, and the inability to accurately estimate U.S. dollar equivalents for Soviet programs. A statement that with a much smaller GNP than the United States (less than one-half) the Soviets probably spend on their space programs more than we do in equivalent resources, is probably a useful approximation. How much more is difficult to support from publically available assessments. U.S. space activities were estimated to cost $26.4 billion in 1988. Based on what little information has been released by U.S. intelligence agencies during the 1980s, conventional wisdom is that the Soviet spending rate is one and one half times that of the United States which would place the Soviet space spending in 1988 in the order of $40 billion.

These high estimates of spending are supported by a view that military space is a absolute, observable priority, in part, because the Soviet Union seeks superiority in space.

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[1] This chapter updates similar chapters appearing on Soviet Space Programs 1971-75, v. II, p. 85-98, and Soviet Space Programs: 1976-80, Part I, p. 329-342. Dr. George D. Holliday was co-author of the earlier chapters.

"GUNS" (MILITARY SPACE) MAY GIVE WAY TO ECONOMIC GROWTH (INVESTMENT ON PERESTROIKA MODERNIZATION) AND "NEW THINKING" UNDER GORBACHEV

Under Mikhail Gorbachev inquiry into the need for military space programs and the burden of continued military space priority may lead to a reexamination and reduced rate of space spending. The burden for new space programs would be onerous and unsustainable if they were found to compete in an unacceptable way with high priority civilian modernization programs—the heart of Gorbachev's Perestroika restructuring program. Given the Gorbachev imperatives, as well as changes in military strategy, "new thinking" in international affairs, possible arms reduction and space cooperation agreements, continuation of the past trend in space spending could well impose an increasingly onerous or unjustifiable burden on priority programs for modernizing the economy. These new factors together or separately might support a decision to reduce the claims of the space program on resources and lead to restructuring of the space budget. However, a second scenario might suggest that the continued high prestige value of international and other civilian space, modernization requirements of military space, and/or the economic utility of commercial space programs might lead the Soviet leadership to continue the trends of the past in spite of some costly tradeoffs. Modernization costs for military space may go up even if new programs are cut; the benefits of expanding prestigious civilian space may likewise increase even if military space receives a diminished priority.

WITH CONTINUED SECRECY AND RELIANCE ON EVIDENCE OF DEPLOYED PROGRAMS, CHANGES IN SPACE PRIORITIES MAY BE DIFFICULT TO DETECT

Evidence of which course is chosen may not be available for some time if we rely primarily on observations of deployed space programs, since these generally have gestation periods of a decade or more. Although not yet visible, more timely evidence may come from indications of a change in the space program's claims as more resources are allocated to civilian economic programs, possibly as alternatives to new space ventures. Policy statements may reflect intent but are not hard evidence of changing future capabilities. If Gorbachev were to change priorities for military programs generally and wish to have us believe that he had downgraded military space, he would do well to practice glasnost in all his space programs, e.g., to open the programs for objective assessment. We in the West would also do well to improve our objective measures of assessment open to public scrutiny.

Space Priority

Since its emergence to prominence in the 1950s, the Soviet space program has reflected an absolute priority derived from its correlation to national political and military goals to a larger extent than the U.S. program. The correlation of Soviet national objectives for military and civilian space and effective implementation of the priority space programs have been facilitated by the apparent central-

ization of decisionmaking in the Politburo of the Communist Party. For most of the Stalinist period and the transitional rule of Nikita Khrushchev, resource allocations to military programs and the total space program (which is predominantly military) were largely fixed or stipulated for Soviet economic planners. The special personal relationship of academician Sergey Korolev and party leader Khrushchev doubtless contributed to the special priority space activity received in the post-Sputnik, early 1960s period. With the passing of the two from the scene, the space priority probably became more institutionalized, less personalized, but no less imperative.

As the military claims on investment funds began to be assessed more critically in the late 1960s, space claims may have come under some increasing scrutiny. There appeared to be an increasing awareness through cost accounting (khozraschet) of the alternative uses of scarce resources; this greater attention to tradeoffs probably extended to the space program. The demands of civilian investment programs for projects such as industrial plants appear to have been given increasing attention. In considering these competing demands for resources, the civilian and nonstrategic military parts of the space budget were probably under more severe scrutiny. Yet, judging by the continued large and impressive programs during the Brezhnev era, such concerns apparently did not result in a lessening of space priority.

From Khrushchev through Brezhnev the requirements for space may have been viewed more as absolute than relative; therefore, economic tradeoffs relating to foregone civilian programs during the 1980s were not as relevant. In assessing the resource burden of the Soviet space program, we have in mind two rather different kinds of questions:

(1) Subjectively, how did the Soviet leadership appear to view the burden of space programs in terms of the options foregone in other endeavors—the opportunity costs? Was this burden considered onerous?
(2) Objectively, what were the quantity and quality of resources made available to the space programs?

From the former measurement of resources devoted to space, we might also be able to throw some light on the question of the value the Soviet leadership placed on the programs. Decision making on the space programs in the Soviet Union and the United States probably resulted from different subjective or leadership views with political and technological considerations dominating Soviet decisions while costs in resources were a more important factor in U.S. judgments. The Soviet leadership's subjective sense of lack of onerous burden—although difficult to assess—might help to explain why the Soviet Union supported programs requiring more resources than those of the U.S. even though the objective cost or resource burden on their smaller economic base was greater.

The perception of objective resource costs may have influenced Soviet decisions on competing with the United States in the "race to the Moon," choosing between piloted and automated flights. While continuing to use Soyuz rather than developing the more expensive shuttle during the 1970s may have had the effect of choos-

ing the less costly alternative, the more subjective political factors seemed to have weighed more heavily on Soviet decisions than alternative resource costs. Moreover, if the combination of prestige and economic gains were deemed important, the political benefits of U.S.-Soviet civilian space cooperation may have made the costs more tolerable.

From Khrushchev through Brezhnev the requirements for military space may have been viewed more as absolute than relative; therefore, the comparative burden of foregone civilian programs outside the space program were not relevant.

The objective question of resource cost is primarily a measurement problem. Attempts to measure, in turn, are limited by the availability and accuracy of Soviet data and by problems of translating Soviet measurements—either in physical or monetary terms—into measurements amenable to international comparisons. If Soviet leaders have been increasingly interested in choices among space and other programs, the accuracy of in house measurements may be presumed to have improved. However, the limitation on disclosure of information in the Soviet system makes such a judgment difficult to document. Looking at the size of the Soviet space program over time by objective physical evidence indicates a large and impressive program, requiring substantial scarce, high quality resources. The characteristics of past programmatic commitments are chronicled in detail throughout these volumes. However, reliable information on economic cost of space spending has been very difficult to obtain. The secrecy system has been and continues to be so pervasive and restrictive that access to the kind of information normally available in the West is severely limited. Moreover, the access of many Soviet officials and professional analysts to Soviet data is also sharply restricted. This important information is so crucial in influencing what an outsider may deduce or what most insiders may know, that a detailed discussion of the Soviet state secrecy laws, their current application, and impact is appropriate in some detail. Glasnost (openness) and a rule of law accepting a public need to know, have not as yet drawn away the veil of secrecy from the Soviet space budgets.

Soviet Secrecy System

For students of the Soviet economy, the strictures of official secrecy continue to be as formidable under Gorbachev as they were in the immediate post-Stalin years. Even in areas that have only marginal national security implications, such as crop forecasts, statistics on grain reserves, production of certain valuable minerals, and balance of payments accounts, economic data are closely guarded, and access is apparently still limited to a very small number of Soviets officials and specialists. The Western observer who wishes to learn about such matters from Soviet publications is required to piece together various bits of related data, make some assumptions about how the Soviet economic system functions, and derive estimates that are often very crude. In military-related activities such as space spending, this task is even more complicated because the absence of even fragmentary published data is virtually absolute. For example, despite the obvious existence of a large

Soviet space program, no space expenditures are listed in the officially published Soviet budget. Soviet space officials add little to our knowledge of this subject, generally limiting themselves to qualitative generalizations about increasing space expenditures.

A wide range of information of an economic nature is included on the Soviet secrecy list still current in 1988; examples of economic items on the list are indicative of the difficulties in analyzing sensitive economic activities such as space spending: [2]

> General information on the location of military-industrial enterprises, production capacities, plans for production of armaments, military equipment and ammunition and data on the fulfillment of the plans in concrete terms as a whole for the U.S.S.R. all-union and union-republic ministries, chief administrations, and enterprises of all-union significance; discoveries and inventions of major scientific and national economic significance before the heads of ministries and departments have granted permission for their publication; *such other information as may be added by the Council of Ministers of the U.S.S.R.* to the list of matters subject to state secrecy. (Italics added)

An important feature of this list is its open-ended nature. In practice, the last item in the list has been used as the basis for keeping secret whatever the leadership believes advantageous. The application of this provision may also be retroactive; all of which reinforces an environment of secrecy.

The penalties for disclosure of state secrets were specified in laws first enacted in 1958 as part of a general legal reform in the early post-Stalin period that are still current. Four articles in the Statute on State Crimes, Articles 1, 2, 12, and 13 and one article in the Law on Military Crimes, Article 23, provide for a variety of penalties depending on the severity of the crime. Penalties range from death for treason and espionage to confinement for 2 to 5 years for smaller offenses, such as "disclosure of state secrets." [3]

The effect of such penalties is to inhibit any Soviet official from speaking or writing on matters that are routinely publicized in the West, unless prior approval has been obtained from top party leaders. One of the valuable aspects of U.S.-U.S.S.R. space cooperation has been the leadership's approval of release of certain kinds of information related to the Soviet space program. Such information, however, has not included data on Soviet space spending.

To be sure, an annual state budget is published with single line items for military and science. Space activities may be partially included in those categories. But there is no reason for confidence in any consistent interpretation of the comprehension, reliability, or comparative meaning of these figures. Likewise, the Soviet pub-

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[2] Valerian, A. and Semen S. Studenkin. Sovetskoe Administrativnoe Pravo (Soviet Administrative Law). Moscow, Gosiurizdat, 1959, cited in Zigurd L. Zile, Robert Sharlet and Jean C. Love. The Soviet Legal System and Arms Inspection. New York, Praeger, 1972. p. 223–224. The 1956 list of state secrets was renewed by decree of Sept. 15, 1966. F. J. M. Feldbrugge (editor) Encyclopedia of Soviet Law, Leiden: Oceans Publishers, 1973. p. 600.

[3] Osnovy ugolovnogo zakonodatel'stva Soiuza SSR i Soiuznykh Resublik, Zakon ob ugolovnoi otvetsvennosti za gosudarstvennye prestupleniia (Basic Criminal Law of the Union of Soviet Socialist Republics). Articles 1, 2, 12, and 13 and Zakonob ugolovnoi otvetsvennosti za voinskie prestupleniia. Article 23, of Dec. 25, 1958; also cited in Ginsburgs and Rusis, op. cit. p. 32–35.

lished information on space activities from which allocations might be derived are sketchy at best. Indeed, it seems fair to state that one of the intents of the Soviet state secrecy laws is to keep allocations to space strictly secret. For Soviet officials who might wish to obtain access to such information and release it in their published works, the criminal penalties of the legal system would seem to be an effective deterrent. Information on Soviet space efforts therefore comes from four sources:

(1) Soviet activities monitored in the West, especially by the United States;
(2) American intelligence estimates built largely on a complex aggregation of relevant but incomplete data;
(3) Selective data released by the Soviet authorities largely for prestige purposes; and
(4) Information obtained from scientific exchanges such as the 1975 Apollo-Soyuz Test Project.

The last two sources are very selective and incomplete measures of the Soviet space program as a whole, especially over time. As a result, we have had to rely heavily on the general estimates of Soviet space spending made by the intelligence agencies in the United States, especially the Central Intelligence Agency and in the Department of Defense. Even though published information by Soviet authorities remains limited, the accuracy of Western estimates on space programs may have improved somewhat over time due to the effective use of technical means such as satellite surveillance. Supplemented by comprehensive economic data, the process of setting parameters and estimating the scope and structure of Soviet space programs might become reasonably reliable, if glasnost were applied to space activities in a comprehensive and consistent fashion. While Gorbachev spoke on the general secrecy problem at the Party Conference on June 28, 1988, saying "The quality of information on international affairs must be drastically improved," there is little implementation to date.[4]

It should also be noted, however, that information on reports prepared by U.S. agencies during the Reagan administration has often been second hand and undocumented, and primarily released through such unofficial sources as the trade press. Moreover, no publication of the methodology used, such as that released by the Central Intelligence Agency to support estimates of Soviet military spending, have been forthcoming in the 1980s. So Soviet secrecy on space spending has been compounded by secrecy in the United States.

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[4] Report by Mikhail Gorbachev to the 19th all-Union Conference of the CPSU, June 28, 1988. Moscow: Novosti Press Documents and Materials. p. 34. While more data have been released under Gorbachev the available data is poorly documented and methodologically flawed. Moreover, the State Committee on statistics (Goskomstat) has considerable leeway to restrict information released that may be detrimental to the State. Apparently that still covers much of the economic data traditionally covered by the Secrecy Acts and certainly space budgets. CIA Directorate of Intelligence. The Impact of Gorbachev's Policies on Soviet Economic Statistics—A Conference Report, SOV-88-10049, July 1988. p. 27, 35.

Space Spending

During the 1980s the Reagan administration has estimated that Soviet space efforts have exceeded those of the United States and the trend of spending suggests a widening of the expenditure gap. In 1982, it was reported that the Defense Department estimated Soviet expenditures at $18 billion—a ratio close to 1.5 times that of the U.S. effort. The U.S. Defense Department was reported further to have estimated a quadrupling of the Soviet space effort by the year 2000 due to aggressive spending in a number of mission areas detailed in this report:

- Energiya , heavy-lift launch vehicle;
- Salyut and Mir Space Stations;
- Space Shuttle;
- Space Plane; and
- Possible Space-Based Weapons

This same 1982 classified defense intelligence study is said to have projected the Soviet space budget for the year 2000 to be approximately $72 billion.[5] The U.S. space budget for 1988 is estimated to be $26.4 billion by the Office of Management and Budget; there are no estimates for the U.S. space budget in the year 2000. According to a French specialist on Soviet space, Alain Dupas, other U.S. official sources have reported:

> Every year about 100 space launches are carried out from the three Soviet launch bases. This situation explains the fact that Soviet space activities are far ahead of the rest of the world in terms of volume: over 600 tons of payload put into near-Earth orbit each year, i.e., three to four times that of the U.S. It also accounts for the importance of the Soviet space industry which according to U.S. sources employs 600,000 people (compared to 300,000 in the U.S.), and accounts for 1.5 percent of the Soviet GNP (compared to 0.5 percent in the U.S.). These quantitative advantages, however, do not signify (or at least not yet) that the U.S.S.R. is ahead of the U.S. in space.[6]

Dupas further cautions,

> In an appraisal of the true situation it is impossible to trust completely either U.S. sources or Soviet claims. U.S. aerospace circles have too much vested interest in making it known that the U.S.S.R. is racing ahead towards space colonization to provide completely objective information. Moreover, this situation is not new, as the history of the 'bomber gap' of the 1950's, and of the 'missile gap' in the early 1960's bears witness—neither of which existed except in the minds of U.S. experts.
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> Nevertheless Soviet space activities are shrouded in an uneasy secrecy, and have a past laden with disguised failures and aborted programmes. Combining diverse information from various U.S. and Soviet sources, independent

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[5] Aviation Week and Space Technology, July 19, 1982, p. 28.
[6] Dupas, Alain. The U.S.S.R.'s Prudent Space Policy. Space Policy, Aug. 1987. p. 241.

> Western observers have therefore come to the conclusion that the U.S.S.R., contrary to its claims, undertook in the 1960's a programme to send a man to the Moon, in response to the Apollo programme, and that it abandoned this programme after the U.S. success. This secrecy in space and military affairs is prejudicial to the U.S.S.R., which at any one time is credited with more potential than it actually has.[7]

Soviet Military Power, 1984 released by the U.S. Department of Defense was bullish on the Soviet space program and its relevance to military capabilities,

> By all measures, the Soviet level of effort devoted to space in the 1980s is increasing significantly over the activities noted in the 1970's. The projected yearly rate of growth of the Soviet space program is expected to outpace both the annual rate of growth in overall Soviet military spending and that of the Soviet gross national product (GNP) for a number of years to come.
>
> The Soviets have embarked upon a long-term, broad-based effort to expand their operational military capability in space. A major Soviet objective is to expand war fighting capability in space and achieve a measure of superiority in that arena. Their technological base is strengthening and is being enhanced by technology transfer from the West. Their launch capability is increasing with the development of new facilities and booster systems. They continue to operate the world's only operational antisatellite system, while they test and develop more sophisticated space weaponry. It is clear the Soviets are striving to integrate their space systems with the rest of their armed forces to ensure superior military capabilities in all arenas.[8]

The level of effort and incremental cost of Soviet space programs in the mid 1980s seem substantial. These represent decisions of the Brezhnev era of military and space dominance in government priorities. The rising cost and objective burden did not appear to be a major issue in the Brezhnev period as the leadership apparently accepted space attainments as absolutely essential.

Burden and Opportunity Costs of the Soviet Space Program

A subjective measure of the economic burden of Soviet space spending is based on how Soviet decisionmakers value accomplishments in space compared to allocation of resources to alternative economic goals that must have been foregone. An objective measure, as noted above, is the amount of resources, measured in rubles and dollars as well as the materials, machinery, scientists and technicians that must have been diverted from other sectors of the economy to the largely military space program. Western defense analysts have been long familiar with this distinction between sub-

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[7] Ibid, p. 239f.
[8] Soviet Military Power 1984, p. 47.

jective and objective evaluation of the burden. Andrew Marshall, Director of Net Assessment in the Defense Department, noted this problem in 1976 in assessing the burden of Soviet defense spending.

> What is critical is a better understanding of how that opportunity cost is perceived by Soviet leadership and society . . . To understand the burden of defense in any useful sense we need to know much more about how such conflicting and reenforcing views work themselves out in the Soviet system. The answer to this sort of question depends upon an understanding of the internal bureaucratic and organizational politics of the decision process which determine the allocation of resources . . . the perceived burden of defense may be increasing over time even though defense takes but a constant or declining share of GNP. Therefore, it is impossible to address the problem of the burden, or the Soviet perception of the burden, without knowing how strongly the Soviet leadership in general, or subgroups of it, are attached to some alternative goals that could be obtained by diverting resources from defense even if the efficiency of the shift of resources is low. Until much more progress is made in these broader dimensions of the burden issue, statements to the effect that the burden of defense upon the Soviets is great or small will not be persuasive.[9]

Thus, in estimating the economic burden of the Soviet space program, ruble and dollar estimates are insufficient to evaluate leadership intent. Our knowledge of Soviet "internal and bureaucratic and organizational politics", various policy statements, and official economic plans give some insights, if not hard evidence, of what priorities are attached to competing economic goals.

Observers of Soviet behavior have made widely differing assessments of the political utility to the Soviet leadership of expanding military space strategic systems in the Brezhnev through the Gorbachev periods. Among the widely differing assessments, one might characterize, as this author did in the earlier editions of this report one as the "Soviet superiority" school and another as the "diminishing marginal political utility" school, illustrating the range of opinion about options open to the Soviet leadership. The "Soviet superiority" school would contend that:

> The Soviet Union has the capacity to expand military-space strategic systems to a level which assures strategic superiority over the United States in the near future. Such strategic superiority can be translated in Soviet political hegemony in various important geographical areas, including West Europe, Asia, and the Mediterranean. Thus, large military-space expenditures may promise such great political benefits that they will be unconstrained by the demands of hard-pressed civilian sectors of the Soviet economy.

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[9] U.S. Congress. Joint Economic Committee. Subcommittee on Priorities and Economy in Government Allocations of Resources in the Soviet Union and China—1975. p. 164–165.

> The 'diminishing marginal political utility' school would contend that: The incremental costs for new military and space programs have become so high and the political utility so low that stabilization or reduction of those priority programs in military space and new civilian investment programs may even favor the latter. At least they would be considered as serious alternatives.[10]

To be sure, these views are oversimplified to suggest the range in official U.S. political and intelligence assessments of Soviet leadership perceptions. The former school of thought, for example, approximates the view of the Department of Defense observers:

> Soviet Military Power 1983 and 1984 outlined the continuing expansion into space of the Soviet drive for military superiority. In the past year, some 80 percent of Soviet space launches have been purely military in nature, with much of the remainder serving both military and civil functions. This is an increase from 70 percent in previous years. The Soviet military space program dominates the USSR's overall space effort. Soviet military doctrine establishes requirements for the military space program.[11]

The latter view comes close to that earlier expressed by former Secretary of State Kissinger and more recently by Soviet Foreign Minister Shevardnadze that both we and the Soviet Union have begun to find that each increment of power does not necessarily represent an increment of usable political strength. In July 1988 Shevardnadze noted:

> Let us now take up a different but equally important question for national security, namely, the economic price of political decision. This is the economic profitability of foreign policy. Here each step has its price, in either adding something or subtracting something from the budget of national well-being. And at times it is too great a substraction. The rough, rash tossing of weights onto the political scales sharply turns the arrow toward a minus.[12]

The current "New Thinking" in Soviet foreign policy under Mikhail Gorbachev suggests a shift in the relative weight of the military factor in the decision making of the Soviet leadership.

Soviet global influence, and development of a more pragmatic foreign policy entails less risk and net cost. Official statements of military strategy stress defensive over offensive systems. This new policy would suggest less emphasis on attaining superiority and a reassessment of foreign commitments to validate their cost from concrete political benefits. The expansion of interest in cooperative programs in space would be consistent with this new policy line.[13]

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[10] Soviet Space Programs: 1976–80, Part I, p. 335.

[11] Soviet Military Power, 1985, p. 43.

[12] Kissinger briefing to congressional leaders. Congressional Record, June 19, 1972. p. S9600; Abridged version of a report given by Foreign Minister E. A. Shevardnadze on 25 July at a conference of the USSR Ministry of Foreign Affairs on the 19th All-Union CPSU Conference: Foreign Policy and Diplomacy, FBIS–SOV–88–18, Annex, Sept. 22, 1988.

[13] Speech of Gorbachev to Party Conference, op. cit., p. 28–30; Primakov, Evgeni. PRAVDA, Mar. 20, 1988. See Garthoff, Raymond. New Thinking in Soviet Military Doctrine. Washington

Continued

Gorbachev's new thinking in international affairs, *if implemented,*[14] *could affect the priority to space programs:*

(1) The new military doctrine emphasizing a defensive posture and a revised view of "reasonable sufficiency" may reduce the need for future military space buildups;
(2) Strategic arms agreements that are verifiable may reduce Soviet strategic forces and weapons in existence and the requirements for new military space programs to permit verification; and
(3) New thinking in international affairs calls for a more pragmatic less military-centered foreign policy, ergo fewer forward deployed forces and less inclination to support programs such as space efforts solely for gaining technological prestige.

Through Gorbachev's Perestroika program for modernization of the Soviet economy, the Soviet Union appears to be belatedly entering the second industrial revolution, attempting through economic modernization to match the "economic miracles" achieved by Japan and the Western European countries during the 1950s and 1960s. If it is not to be left behind by the advanced industrial nations in the 21st century, the USSR must also try to initiate participation in the current technological-information revolution.

Upgrading and modernizing Soviet plant and capacity and raising the technological level of the economy toward the Western level has become a top priority, some would say an overriding priority of Gorbachev. Sophisticated defense analysts such as Andrew Marshall note the rising objective burden of military (including military space) programs and estimate that by his, or Western, objective measures, defense and related programs claim 20–30 percent of the value of material production rather than the 14–17 percent estimated by CIA and DIA. However, his view is that the Soviet leadership perceptions under Gorbachev have not changed: "The Soviet military program is probably not seen as a cost or burden or diversion of resources from other more highly valued uses." [15] To others, the rhetoric of the Perestroika restructuring and modernization suggest that it is now a "highly valued use" of scarce resources. Moreover "new thinking" suggests the perceived need for military space programs have been reduced. Some believe a continuation of the past trend of space spending should be considered both an "onerous" subjective and objective burden under Gorbachev.

The cost of the space program in civilian non-space options foregone for entering the third technological-industrial revolution is acknowledged by DOD's Soviet Military Power 1987 in the following:

Quarterly, Summer 1988, for further discussion of the military's response to reasonable sufficiency, and references to Military Thought. MccGwire, Michael. Rethinking War: the Soviets and European Security. Brookings Review, Spring 1988. The Clash Between Civilian Specialists and the Soviet Military over Reasonable Sufficiency. Foreign Broadcast Information Service, Dec. 4, 1987. Statement of Mikhail S. Gorbachev to Plenary Meeting of the United Nations General Assembly, Dec. 7, 1988.

[14] Civilian space may receive increased emphasis due to prestige and desired international image. (cf. previous chapter). The offer by Secretary Gorbachev to convert the Krasnoyarsk radar station to civilian space, may be a case in point. Washington Post, Sept. 16, 1988. p. 1; U.N. speech, op. cit.

[15] Marshall, Andrew W. Commentary in Defense Industry and Economy Section. Gorbachev's Economic Plans Volume 1. Washington, U.S. Govt. Print. Off., Nov. 23, 1987. p. 481.

> The high priority the Soviets are giving to their space program is reflected in the rapid overall growth of the program, *a program that is absorbing a large share of the nation's most advanced and productive technology since 1980.* The estimated dollar costs of the Soviet space effort have more than doubled, owing largely to programs for the manned space stations, new launch vehicles, supporting facilities, and the shuttle orbiter. The projected rate of growth in the space program, driven by the ambitious space-based manned program and future communications satellites, is expected to outpace overall trends in both military spending and GNP well into the future.[16] (Italics added)

U.S. Air Force Secretary Edward C. Aldridge, Jr., after a visit with Soviet space officials in July 1988, noted the budget pressures expressed to him by those responsible for Soviet military space programs. Space cooperation was reportedly seen as a means to stabilize their funding for chosen programs by gaining access to U.S. technology.[17]

Alexandr I. Dunayev, head of Glavkosmos, indicated civilian space programs were being put on a "self financing" basis. Just how profitable commercial space will be is yet to be demonstrated. On the occasion of the completion of a long duration space station mission by two cosmonauts, Yuriy Romanenko and Alexsandr Alexsandov, Dunayev stressed the need to justify space outlays by economic gains.[18] Such comments stressing budgetary problems and the need to justify the economic burden of space programs by spin-off economic benefits were also reportedly reflected in Dunayev's comments to a Space Future Forum in Moscow in October 1987. Academician Roald Z. Sagdeyev, head of the Soviet Institute for Space Research is said to have reflected the same concerns.[19]

Military space allocations may be more likely to be reduced in terms of the growth in military space rather than in absolute spending levels. Nevertheless, these increments are quite important as, with slow growth and rising demand for quality products, materials, and skilled manpower, a deferral of new military space programs could release a margin of resources that might be critical to increased modernization and productivity under Perestroika. If, for example, new capacity for the next generation of space vehicles were deferred, the impact on resources available for civilian modernization could be substantial. Some analysts such as Jan Vanous and Bryan Roberts, using the PlanEcon Model, would argue that it is an "either-or" choice in conventional weaponry: Gorbachev can have tanks or tractors, not both.[20]

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[16] Soviet Military Power 1987, p. 58. Underline added.
[17] Aerospace Daily, July 19, 1988, p. 90.
[18] FBIS, Jan. 21, 1988, Sov-88-013 from Moscow Tass, Jan. 20, 1988.
[19] Aerospace Daily, Oct. 20, 1987, p. 101.
[20] Vanous, Jan and Bryan Roberts. Time to Choose Between Tanks and Tractors: Why Gorbachev Must come to the Negotiating Table or Face a Collapse of His Ambitious Modernization Program. PlanEcon Report, June 27, 1986. CIA/DIA report, Gorbachev's Economic Program: Problems Emerge, to the Subcommittee on National Security Economics of the Joint Economic Committee, Apr. 13, 1988.

Assuming that high marginal costs, and reduced political utility represent the current Soviet leadership perception of military and space programs we might consider what other options are at stake. In preparing for the Thirteenth Five-Year Plan (1991–95), the requirements for increased investment may run well ahead of the anticipated growth. The machine building needs for Gorbachev's restructuring may take the lion's share of new capacity. If so, this could draw resources away from Soviet programs that may be considered analogous to the U.S. Strategic Defense Initiative.

The technologies under development to support the U.S. Strategic Defense Initiative (SDI) are creating a pool of innovative concepts which will have potential applicability to the U.S. defense industry in strong interaction with the civilian sector; for example, Battle Management/Command, Control and Communications requires the development of computer hardware and software on an unprecedented scale; kinetic energy weapon systems require research on microelectronic controls, advanced infrared and radar sensors, compact chemical propulsion devices, and electro-magnetic launchers which could lead to advanced anti-tactical weapons and propulsion systems; directed energy weapon systems create a focal point for laser research, particle beam concepts, and large space structures. Relevant systems analysis involves studies of large space transportation systems paving the way for space exploration in the 21st century. Finally, SDI countermeasure studies are evaluating the vulnerability of defense systems to possible offensive responses which could drive improvements in technologies such as nuclear radiation hardened electronic means to counter a Soviet maneuvering missile threat. The scale of the U.S. SDI effort will probably incline the Soviets to restructure their efforts in the reform of research and development planning. Assuming the same would be true in the Soviet Union, the dual military-civilian character of SDI technology may require Gorbachev to coordinate technological reforms for both civilian and military needs; for example, investment in computer technology has a military and civilian commonality. Or civilian demands of Perestroika may be more "highly valued" than military space programs.[21]

It should be emphasized that the specialized, high-technology inputs of the Soviet space program are not easily convertible to civilian investment needs in the short run. If Soviet space and military programs are to be slowed down, one might expect the military space share to retain or expand its portion of the total space budget compared to civilian space programs, as has been the case in the past. However, if the U.S.-U.S.S.R. cooperative programs expand, their focus on civilian programs may provide an incentive for the Soviets to maintain a strong civilian program and to keep the prestige of a proud scientific community intact; Soviet leaders may show a preference for the visible, civilian program. If, then,

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[21] Hardt, John. Soviet Economic Constraints on Defense to Year 2000. U.S. Policy Toward the Soviet Union Atlantic Council, University Press of America. New York-London, p. 225–239; Cooper, Julian. The Elite of the Defence Industry Complex. In Elites and Political Power in the USSR, edited by David Lane. Aldershot, Hants, England, Elgar Brookfield, VT. USA, 1988. Hardt, John and Boone, Jean. Computer-Assisted Third Industrial Revolution in the USSR: Policy Implication for the Soviet Union and the United States. In Staar, Richard. The Future Information Revolution in the USSR. New York, Crane Russak and Company, 1988.

the Soviet leaders were to move toward a cooperative U.S.-U.S.S.R. program for Mars exploration, for example, the civilian space program might be among the higher priority claimants.

The priority accorded Soviet space programs in the planning period ahead will probably depend primarily on the leadership's perception of the economic costs and political benefits of new programs. If considerable political gain is possible in the world arena, the high priority for space will continue and even increase. If the gains are perceived as of questionable value, the pressing claims of alternative civilian investment programs may be expected to increase in weight.

If the "Soviet superiority" view is in fact accurate, the notion of burden, opportunity costs or tradeoffs between military and space programs versus civilian (non-space) investment would not seem very relevant. If military superiority were attainable and its fruits could be translated in meaningful political shifts in power relationships, the Soviet leadership priorities would probably be in favor of the traditional "guns" or military and military space programs. However, if the perception of rising-cost, diminishing-utility proves dominant, a reduction of relative military and military space claims on resources would be eminently logical.

Unfortunately, we do not have sufficient knowledge of the Soviet leadership's motivations to determine which of these views is closest to what Soviet leaders are not only thinking but implementing. Moreover, even a reduced priority to military space expansion may lead to larger space spending and burden, if modernization of military space is required in a process of defense reduction due to changed policy and/or arms agreements.

A continuation of Soviet priority toward space, albeit costly in the face of civilian restructuring and modernization needs, would appear to have been retained if deployed vehicles are the sole or primary test of policy. With gestation periods of a decade or more for sophisticated programs from initial resource commitment to deployment, current evidence may glow like long dead stars as results of Brezhnev-period decisions which are only now reaching us. If we are to take seriously Gorbachev's statements on changed priorities we must have much more openness about Soviet programs from resource commitment to space vehicle deployment, and this increased openness must be accompanied by greater openness of intelligence information on these programs in the United States to permit public understanding and informed debate.

MASTER LOG OF SOVIET SPACE LAUNCHES: 1981–87 [1]

This table includes all launches whose payloads reached sustained Earth orbit or escape beyond Earth, with an identification of individual payloads as best can be determined. It also includes suborbital flights such as vertical space probes when the vehicles used equal or approach the size of vehicles used for orbital flight, if these suborbital flights have been acknowledged in Soviet releases.

The starting point in compiling the table has been to use TASS releases provided by the BBC Monitoring Service, Caversham Park, Reading, England, for the basic listing with the initial orbital elements. When such elements have not been given in the TASS announcements, or when the operational orbit differs significantly from that announced, additional data has been computed from the two line orbital elements disseminated by the Goddard Space Flight Center. Such additional data is denoted by an asterisk and is the responsibility of the compiler.

It must be recognized that any such table is only the best which can be produced at a particular time. Fresh data may become available in official Soviet histories, new insights by Western analysts, and disclosures about current activities which then make it possible to understand better the precursors.

THE HEADINGS

Payload name

For the most part these are announced by TASS. However one flight, in June 1985, was not acknowledged by the Russians, yet was detected by Western sensors. Also, in a large number of flights there are implicit payloads which have not been named by the Russians, although often their functions are described by TASS. The most obvious are the rocket stages or platforms from which satellites or probes are launched into deep space, or to eccentric orbit, or to geosynchronous orbit. Although earlier versions of this table listed such objects as Tyazheliy Sputniks they are not included here since recently available information on the Proton, or D–1e, launch vehicle presented in volume 1 shows that the restartable fourth stage performs this function.

Often some years later, the scientific findings from pickaback payloads are published in the open literature by the Russians. These, and objects which might possibly be maneuvering engines, separated toward the close of recoverable missions are not listed in this table.

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[1] This table is a continuation of the tables provided in earlier editions of this report. Launches for the period 1957–80 will be found in Soviet Space Programs: 1976–80, Pt. 1, Appendix III. p. 395–445.

Designator

The designator column lists an abbreviation of the COSPAR international numbering system. The first two digits give the year of launch. These are followed by a sequential Arabic numeral for each launch, plus a capital Roman letter for each separate tracked object connected with a given flight. Flights not attaining orbit do not have designators.

Launch date

As far as can be determined, the listed date is based upon Greenwich Mean Time (GMT). Confusion can arise with launches occurring between 2100 and midnight GMT, when the TASS announcement, based on Moscow Time, will place the launch in the day ahead. With the introduction of Moscow Summer Time, the period of confusion is from 2000 to midnight GMT.

Site

Some Soviet launches come from the Baykonur Cosmodrome, which in the West is usually referred to as Tyuratam (TT), the railway station closest to this site in Kazakhstan. Additional launches come from the Northern Cosmodrome, now acknowledged to be near Plesetsk (PL), on the railway between Moscow and Archangel. Finally a smaller number of space launches come from Kapustin Yar (KY), on the lower reaches of the Volga River below Volgograd. The launch sites have been identified with a high degree of certainty. Usually the launch site can be derived from the orbital inclination. Confirmation is obtained by computing the launch time from the "Goddard two line elsets" as that time at which a given site lies in the orbital plane on the day of launch and verifying that the result is consistent with the computed ground track for the initial revolution.

Launch vehicle

The characteristics, capacities, and interrelationships among the various Soviet launch vehicles is developed in detail in volume 1 of this report. In brief, as each new first stage vehicle has come into use, it has been assigned a sequential capital Roman letter, skipping those letters also used as suffixes in existing vehicles. Because it is not always possible from available public information to define and describe all the upper stages used, the first combination brought into use is called "1", and if this is markedly modified, the new version becomes "2". In some cases there is a third designator if the 1 or 2 versions of the launch vehicle have an extra final stage added (a third or fourth stage), and this is indicated by an additional Roman letter in lower case, such as "e" for escape or "m" for maneuvering. In other cases a maneuvering or retro capability may be integral to the payload, and is not given a letter designation. This nomenclature system, due to the late Dr. Charles S. Sheldon II, first appeared in TRW Space Log and is widely used. It is used here in preference to the Department of Defense "SL" designators for consistency with earlier versions of the table and because the DOD system conveys no sense of vehicle structure or interrelationship.

Apogee

This figure in kilometers represents the high point of the orbit. In the TASS announcements this would appear to be the actual measurement of the height above the Earth's surface at the subsatellite point and, due to the oblate sphericity of the Earth, is dependent upon the location of that point. For orbits computed by the compiler it is the height above a mean spherical Earth of radius 6378.1 km, the equatorial radius.

Perigee

This figure is the one corresponding to apogee but represents the lowest point of the orbit with the same provisos as stated in the preceding section.

Inclination

This is the angle between the orbital plane and the Earth's equatorial plane. To a first approximation it may be taken to denote the maximum latitude of the ground track north and south of the Equator. Orbits with inclinations greater than 90 o are said to be retrograde.

Orbital period

This is stated in minutes as the time to complete one orbit of the Earth from one northbound equator crossing (ascending node) to the next. The nodal period defined in this way differs from the sidereal period measured from the time of crossing a given longitude to the next or the anomalistic period measured from one perigee passage to the next.

When all four orbital parameters quoted differ significantly from those announced by TASS, the asterisk denoting this fact will be found following the orbital period. In the few instances when only one orbital parameter differs due to an omission or typographical error in the TASS announcement the asterisk is placed after those parameters.

Down

This is based on GMT and is the date of natural decay in the Earth's atmosphere, landing on recovery, or de-orbiting for safety measures.

Life

This is stated in days and is the difference between the dates of launch and decay, recovery or de-orbiting. The abbreviation for disintegration, "dis", is used in this column for satellites which are deliberately destroyed or which fragment accidentally.

Mission and remarks

The mission identification is occasionally announced by TASS, but more often has been inferred. By grouping all the flights with similar characteristics, it is usually possible to determine the main purpose of the flight. However, sometimes differences of mission depend on fairly subtle indicators and some caution is required. Clues come from the orbital elements. Each mission class usually

has one or more of a limited number of launch inclinations at which it is flown. Likewise, there are typical orbital patterns of altitude for photographic reconnaissance or Earth remote sensing missions, electronic ferrets, navigation satellites, meteorological satellites, geodetic satellites, early warning satellites, the various categories of communications satellites, and so forth. Identifications given are the responsibility of the compiler and he is most grateful to his colleagues in the Kettering Group of space observers for their reports of visual observations and radio intercepts from Soviet satellites which, by their frequencies, modulation and telemetry formats, provide supporting evidence for his identifications.

Overall, most missions can be determined reliably, but a few missions remain obscure, either indefinitely, or until repetitive patterns finally give confidence that the first flights of that pattern are understood. There is always an outside chance that a purpose has been hidden by choosing external flight characteristics which would mislead. It should also be remembered that a flight may be multi-purpose (i.e., military photography, electronic ferreting, engineering tests, and scientific experiments in a single payload). Also, early vehicle tests can be counted arbitrarily as vehicle tests per se or as precursors to some later application.

This column also provides supplemental information where appropriate, although in less detail than as carried in the tables and chapters of the main text. For example, the names of cosmonauts, the fact of docking, and the nature of some scientific experiments is given as an aid to the reader.

Abbreviations, when employed, are generally self explanatory. However, in the cases of photographic reconnaissance satellites, end of mission recovery of a third generation satellite is denoted by an 'R' and de-orbiting of a fourth generation satellite by a 'D'.

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
1981											
Cosmos 1237	81-01A	Jan 6	PL	A-2	410	207	72.9	90.4	1/20/81	14	Photorecon, R
					417	356	72.9	92.3*			
Molniya 3-14	81-02A	Jan 9	PL	A-2e	40784	485	62.5	736			Communications
					39925	448	62.8	718.1*			
Cosmos 1238	81-03A	Jan 16	PL	C-1	1976	411	83	109.1			Minor military
Cosmos 1239	81-04A	Jan 16	PL	A-2	265	222	82.3	89	1/28/81	12	Photorecon/geodesy, R
Cosmos 1240	81-05A	Jan 20	TT	A-2	277	178	64.9	89.8	2/17/81	28	Photorecon, D
Cosmos 1241	81-06A	Jan 21	PL	C-1		1000	65.8	105.0			ASAT target, intercepted by Cosmos 1243 & Cosmos 1258
					1011	977	65.8	105.0*			
Progress 12	81-07A	Jan 24	TT	A-2	299	188	51.6	89.1	3/20/81	55	Freighter to Salyut 6, docked 1/26-3/19/81
Cosmos 1242	81-08A	Jan 27	PL	A-1	684	635	81.2	97.6			ELINT 1st generation
Molniya 1-49	81-09A	Jan 30	PL	A-2e	40801	464	62.8	736			Communications
					39835	519	62.9	717.8*			
Cosmos 1243	81-10A	Feb 2	TT	F-1m	1026	316	66	98	2/2/81	<1	ASAT, intercepted Cosmos 1241 on 2nd rev
Intercosmos 21	81-11A	Feb 6	PLPL	C-1	520	475	74.0	94.5	7/7/82	516	Science
Cosmos 1244	81-13A	Feb 12	PL	C-1	1024	979	82.9	105			Military navsat #1
Cosmos 1245	81-14A	Feb 13	PLPL	A-2	403	208	72.9	90.3	2/27/81	14	Photorecon, R
					416	356	72.8	92.3*			
Cosmos 1246	81-15A	Feb 18	TT	A-2	292	202	64.9	89.2	3/13/81	23	Photorecon, D
Cosmos 1247	81-16A	Feb 19	PL	A-2e	39540	613	62.8	709			Early warning
					39736	618	63.0	717.8*			
Cosmos 1248	81-20A	Mar 5	PL	A-2	371	180	67.1	89.7	4/4/81	30	Photorecon, D
Cosmos 1249	81-21A	Mar 5	TT	F-1m	282	258	65	89.6			RORSAT, raised 6/19/81
					985	898	65.0	103.9*			
Cosmos 1250-1257	81-22A-H	Mar 6	PL	C-1	1500	1450	74	115			Tactical communications, octuple launch
Soyuz-T 4	81-23A	Mar 12	TTTT	A-2	331	250	51.6	90.1	5/26/81	75	Manned to Salyut 6, V Kovalenok & V Savinykh, docked 3/13-5/26/81
Cosmos 1258	81-24A	Mar 14	TTTT	F-1m	1032	322	65.8	98	3/14/81	<1	ASAT, intercepted Cosmos 1241 on 2nd rev
Cosmos 1259	81-26A	Mar 17	TT	A-2	405	215	70.4	90.4	3/31/81	14	Photorecon, R
					414	350	70.4	92.2*			
Raduga 8	81-27A	Mar 18	TT	D-1e		36950	0.4	1477			Geosync communications, Statsionar-2
					36000	35561	0.5	1435.7*			
Cosmos 1260	81-28A	Mar 21	TT	F-1-m	458.7	435.2	65.0	93.3	5/22/82	428	EORSAT
Soyuz 39	81-29A	Mar 22	TT	A-2	320	271	51.6	90.3	3/30/81	8	Manned to Salyut 6, V Dzhanibekov & J Gurragcha (Mongolia), docked 3/23-3/30/81
Molniya 3-15	81-30A	Mar 24	PL	A-2e	40655	641	62.8	736			Communications
					39732	624	62.7	717.8*			
Cosmos 1261	81-31A	Mar 31	PL	A-2e	40170	615	62.8	710			Early warning
					39766	611	63.0	718.2*			
Cosmos 1262	81-32A	Apr 7	PL	A-2	418	207	72.9	90.4	4/21/81	14	Photorecon, R
Cosmos 1263	81-33A	Apr 9	PL	C-1	1988	403	83	109.1			Minor military
Cosmos 1264	81-35A	Apr 15	TT	A-2	411	216	70.4	90.5	4/29/81	14	Photorecon, R
					416	361	70.4	92.4*			
Cosmos 1265	81-36A	Apr 16	PL	A-2	317	210	72.9	89.4	4/28/81	12	Photorecon, R
Cosmos 1266	81-37A	Apr 21	TT	F-1m	278	259	65	89.65			RORSAT, raised 4/29/81
					965	891	64.8	103.6*			
Cosmos 1267	81-39A	Apr 25	TT	D-1	278	200	51.6	89	7/29/82	460	Module to Salyut 6, docked 6/19/81
Cosmos 1268	81-40A	Apr 28	TT	A-2	391	217	70.4	90.3	5/12/81	14	Photorecon, R
Cosmos 1269	81-41A	May 7	PL	C-1	833	797	74	100.9			Store-dump communications

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
Soyuz 40	81-42A	May 14	TT	A-2	307	260	51.6	90.1	5/22/81	8	Manned to Salyut 6, L Popov & D Prunariu (Romania), docked 5/15-5/22/81
Meteor 2-7	81-43A	May 14	PL	A-1	904	868	81.3	102.5			Meteorology
Cosmos 1270	81-45A	May 18	TT	A-2	370	180	64.9	89.7	6/17/81	30	Photorecon, D
Cosmos 1271	81-46A	May 19	PL	A-1	670	628	81.2	97.5			ELINT 1st generation
Cosmos 1272	81-47A	May 21	TT	A-2	403	217	70.4	90.4	6/4/81	14	Photorecon, R
					417	362	70.4	92.4*			
Cosmos 1273	81-48A	May 22	PL	A-2	277	211	82.3	89.2	6/4/81	13	Photorecon/Earth resources (Priroda), R
Cosmos 1274	81-52A	Jun 3	PL	A-2	380	183	67.2	89.8	7/3/81	30	Photorecon, D
Cosmos 1275	81-53A	Jun 4	PL	C-1	1026	983	83	104.9	6/24/81	dis	Military navsat #6
Molniya 3-16	81-54A	Jun 9	PL	A-2e	40837	471	62.8	736			Communications
					39890	465	62.8	717.8*			
Cosmos 1276	81-55A	Jun 16	PL	A-2	265	224	82.3	89.1	6/29/81	13	Photorecon/Earth resources, R
Cosmos 1277	81-56A	Jun 17	TT	A-2	393	216	70.4	90.3	7/1/81	14	Photorecon, R
					416	360	70.4	92.3*			
Cosmos 1278	81-58A	Jun 19	PL	A-2e	40165	614	62.8	726			Early warning
					39754	628	62.9	718.3*			
Molniya 1-50	81-60A	Jun 24	PL	A-2e	40640	645	62.8	736			Communications
					39741	616	62.9	717.8*			
Ekran 7	81-61A	Jun 26	TT	D-1e		35636	0.4	1426			Geosync DBS, Statsionar-1 (should have been Statsionar-T?)
					35789	35783	0.0	1436.0*			
Cosmos 1279	81-62A	Jul 1	TT	A-2	385	218	70.4	90.3	7/15/81	14	Photorecon, R
					419	358	70.4	92.4*			
Cosmos 1280	81-63A	Jul 2	PL	A-2	312	222	82.3	89.5	7/15/81	13	Photorecon/Earth resources (Priroda), R
					273	258	82.3	89.9*			
Cosmos 1281	81-64A	Jul 7	PL	A-2	419	208	72.8	90.4	7/21/81	14	Photorecon, R
					415	357	72.8	92.3*			
Meteor 1-31	81-65A	Jul 10	TT	A-1	688	611	97.9	97.6			Meteorology, remote sensing
Iskra 1	81-65B				(1)	(1)	(1)	(1)			Amateur radio
					663	638	98.0	97.8*			
Cosmos 1282	81-66A	Jul 15	TT	A-2	357	179	64.9	89.6	8/14/81	30	Photorecon, D
Cosmos 1283	81-67A	Jul 17	PL	A-2	278	184	82.3	88.9	7/31/81	14	Photorecon/Earth resources, R
					372	325	82.3	91.6*			
Cosmos 1284	81-68A	Jul 29	PL	A-2	270	195	82.3	88.8	8/12/81	14	Photorecon/Earth resources, R
					370	325	82.3	91.6*			
Raduga 9	81-69A	Jul 30	TT	D-1e		36990	0.4	1477			Geosync communications, Statsionar-2
					35831	35749	0.4	1436.2*			
Cosmos 1285	81-71A	Aug 4	PL	A-2e	40165	630	62.8	726			Early warning
Cosmos 1286	81-72A	Aug 4	TT	F-1m	453	433	65	93.24	10/16/82	438	EORSAT
Cosmos 1287-1294	81-74A-H	Aug 6	PL	C-1	1508	1446	74	115.2			Tactical communications, octuple launch
Intercosmos 22 [Bulgaria 1300]	81-75A	Aug 7	PL	A-1	906	825	81.2	101.9			Science
Cosmos 1295	81-77A	Aug 12	PL	C-1	1026	966	82.9	104.8			Military navsat #5
Cosmos 1296	81-78A	Aug 13	PL	A-2	377	181	67.2	89.8	9/13/81	31	Photorecon, D
Cosmos 1297	81-79A	Aug 18	PL	A-2	389	209	72.9	90.2	8/30/81	12	Photorecon, R
Cosmos 1298	81-80A	Aug 21	TT	A-2	351	179	64.9	89.5	10/2/81	42	Photorecon, D
Cosmos 1299	81-81A	Aug 24	TT	F-1m	281	250	65.0	89.7			RORSAT, raised 9/6/81
					984	910	65.1	104.0*			
Cosmos 1300	81-82A	Aug 24	PL	F-2	675	648	82.5	97.7			ELINT 2nd generation
Cosmos 1301	81-83A	Aug 27	PL	A-2	300	224	82.3	89.4	9/10/81	14	Photorecon/Earth resources, R

					272	259	82.3	89.9*				
Vertikal 9		Aug 28	KY	C	500				8/28/81	<1	Geophysical probe, Intercosmos	
Cosmos 1302	81-84A	Aug 28	PL	C-1	824	783	74	100.8			Store-dump communications	
Cosmos 1303	81-86A	Sep 4	TT	A-2	398	216	70.4	90.4	9/18/81	14	Photorecon, R	
					416	361	70.4	92.3*				
Cosmos 1304	81-87A	Sep 4	PL	C-1	984	917	83	104			Civil navsat #12	
Cosmos 1305	81-88A	Sep 11	PL	A-2e	13870	648	63	264			Molniya launch failure	
Cosmos 1306	81-89A	Sep 14	TT	F-1m	494	156	65	90.9	7/16/82	305	EORSAT	
					462	409	65.0	93.3*				
Cosmos 1307	81-90A	Sep 15	PL	A-2	419	209	72.9	90.4	9/29/81	14	Photorecon, R	
					418	356	72.9	92.3*				
Cosmos 1308	81-91A	Sep 18	PL	C-1	1017	978	82.9	104.9			Military navsat #6	
Cosmos 1309	81-92A	Sep 18	PL	A-2	282	225	82.3	89.2	10/1/81	13	Photorecon/geodesy, R	
Oreol 3	81-94A	Sep 21	PL	F-2	1920	380	82.6	108.2			Science [France]	
Cosmos 1310	81-95A	Sep 23	PL	C-1	524	478	65.9	94.6	8/28/83	699	Minor military	
Cosmos 1311	81-97A	Sep 28	PL	C-1	521	470	83	94.5			Minor military	
Cosmos 1312	81-98A	Sep 30	PL	F-2	1531	1495	82.6	116			Geodesy 2nd generation	
Cosmos 1313	81-99A	Oct 1	TT	A-2	314	214	70.4	89.5	10/15/81	14	Photorecon, R	
					291	206	70.4	89.5*				
Cosmos 1314	81-101A	Oct 9	PL	A-2	263	220	82.3	89	10/22/81	13	Photorecon/Earth resources (Priroda), R	
Raduga 10	81-102A	Oct 9	TT	D-1e		35900	0.4	1442			Geosync communications, Statsionar-3	
					35808	35763	0.4	1435.9*				
Cosmos 1315	81-103A	Oct 13	PL	A-1	685	628	81.2	97.7			ELINT 1st generation	
Cosmos 1316	81-104A	Oct 15	TT	A-2	407	215	70.3	90.5	10/29/81	14	Photorecon, R	
					275	231	70.3	89.6*				
Molniya 3-17	81-105A	Oct 17	PL	A-2e	40644	649	63	736			Communications	
					39744	612	62.9	717.8*				
Venera 13	81-106A	Oct 30	TT	D-1e							Soft landed on Venus, 3/1/82	
					222	177	51.6	88.4*				
Cosmos 1317	81-108A	Oct 31	PL	A-2e	40165	636	62.9	726			Early warning	
					39719	621	62.9	717.5*				
Cosmos 1318	81-109A	Nov 3	PL	A-2	379	183	67.2	89.8	12/4/81	31	Photorecon, D	
Venera 14	81-110A	Nov 4	TT	D-1e							Soft landed on Venus, 3/5/82	
					213	171	51.6	88.3*				
Cosmos 1319	81-112A	Nov 13	TT	A-2	400	216	70.4	90.4	11/27/81	14	Photorecon, R	
					415	348	70.4	92.2*				
Molniya 1-51	81-113A	Nov 17	PL	A-2e	39117	472	62.8	720			Communications	
					39861	496	62.9	717.8*				
Bhaskara 2	81-115A	Nov 20	KY	C-1	557	514	50.7	95.2			Science [India]	
Cosmos 1320-1327	81-116A-H	Nov 28	PL	C-1	1632	1507	74	117			Tactical communications, octuple launch	
Cosmos 1328	81-117A	Dec 3	PL	F-2	677	647	82.5	97.8			ELINT 2nd generation	
Cosmos 1329	81-118A	Dec 4	TT	A-2	283	237	65	89.5	12/18/81	14	Photorecon, R	
RS 3-8	81-120A-F	Dec 17	PL	C-1	1794	1685	83.0	120.9			Amateur radio	
Cosmos 1330	81-121A	Dec 19	TT	A-2	403	177	70.4	90	1/19/82	31	Photorecon, D	
Vertikal 10		Dec 21	KY	C	1510				12/21/81	<1	Geophysical probe, Intercosmos	
Molniya 1-52	81-123A	Dec 23	TT	A-2e	38990	485	63	699			Communications	
					39840	514	62.9	717.8*				
1982												
Cosmos 1331	82-01A	Jan 7	PL	C-1	816	776	74	100.7			Store-dump communications	
Cosmos 1332	82-02A	Jan 12	PL	A-2	275	218	82.3	89.1	1/25/82	13	Photorecon/geodesy, R	
					250	211	82.3	89.1*				
Cosmos 1333	82-03A	Jan 14	PL	C-1	1029	989	82.9	105			Military navsat #3	

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
Cosmos 1334	82-05A	Jan 20	PL	A-2	315	206	72.9	89.4	2/3/82	14	Photorecon, R
					294	230	72.9	89.8*			
Cosmos 1335	82-07A	Jan 29	PL	C-1	535	487	74	94.7	4/5/87	1892	Minor military
Cosmos 1336	82-08A	Jan 30	TT	A-2	379	179	70.4	89.8	2/26/82	27	Photorecon, D
Ekran 8	82-09A	Feb 5	TT	D-1e		35658	0.4	1429			Geosync DBS
					35805	35774	0.6	1436.1*			
Cosmos 1337	82-10A	Feb 11	TT	F-1m	456	436	65	93.3	7/25/82	164	EORSAT
Cosmos 1338	82-11A	Feb 16	PL	A-2	393	208	72	90.2	3/2/82	14	Photorecon, R
					416	358	72.9	92.3*			
Cosmos 1339	82-12A	Feb 17	PL	C-1	1029	975	82.9	104.8			Civil navsat #14
Cosmos 1340	82-13A	Feb 19	PL	A-1	679	636	81.2	97.6			ELINT 1st generation
Molniya 1-53	82-15A	Feb 26	PL	A-2e	40765	490	62.8	735			Communications
					39883	471	62.9	717.8*			
Cosmos 1341	82-16A	Mar 3	PL	A-2e	40165	614	62.8	709			Early warning
					39708	649	62.9	717.8*			
Cosmos 1342	82-18A	Mar 5	PL	A-2	326	207	72.9	89.5	3/19/82	14	Photorecon, R
					303	230	72.9	89.9*			
Gorizont 5	82-20A	Mar 15	TT	D-1e		36320	0.7	1463			Geosync communications
					36632	35242	0.7	1436.0*			
Cosmos 1343	82-21A	Mar 17	PL	A-2	314	208	72.9	89.4	3/31/82	14	Photorecon, R
					288	229	72.8	89.7*			
Molniya 3-18	82-23A	Mar 24	PL	A-2e	40165	656	62.9	736			Communications
					39726	632	62.9	717.8*			
Cosmos 1344	82-24A	Mar 24	PL	C-1	1023	987	82.9	105			Military navsat #1
Meteor 2-8	82-25A	Mar 25	PL	F-2	976	954	82.5	104.2			Meteorology
Cosmos 1345	82-26A	Mar 31	PL	C-1	550	507	74	95.2			ELINT
Cosmos 1346	82-27A	Mar 31	PL	A-1	675	623	81	97.6			ELINT 1st generation
							81.2*				
Cosmos 1347	82-28A	Apr 2	TT	A-2	364	181	70.4	89.7	5/22/82	50	Photorecon, D
					340	173	70.4	89.7*			
Cosmos 1348	82-29A	Apr 7	PL	A-2e	39342	613	62.8	709			Early warning
					39747	604	62.9	717.7*			
Cosmos 1349	82-30A	Apr 8	PL	C-1	1025	948	83	105			Military navsat #4
Cosmos 1350	82-32A	Apr 15	PL	A-2	380	181	67.2	89.8	5/16/82	31	Photorecon, D
Salyut 7	82-33A	Apr 19	TT	D-1	278	219	51.6	89.2			Space station
Iskra 2	82-33C				345	335	51.6	91.3*	7/9/82	81	Amateur radio, launched from Salyut 7, 5/17
Iskra 3	82-33AD				346	345	51.6	91.4*	12/16/82	46	Amateur radio, launched from Salyut 7, 11/18 after delivery by Progress 16
Cosmos 1351	82-34A	Apr 21	KY	C-1	555	349	50.7	93.5	3/14/83	327	Minor military
Cosmos 1352	82-35A	Apr 21	TT	A-2	383	216	70.4	90.2	5/5/82	14	Photorecon, R
					415	349	70.4	92.2*			
Cosmos 1353	82-36A	Apr 23	PL	A-2	269	218	82.3	89.1	5/6/82	13	Photorecon/Earth resources (Priroda), R
Cosmos 1354	82-37A	Apr 28	PL	C-1	829	795	74	101			Store-dump communications
Cosmos 1355	82-38A	Apr 29	TT	F-1m	459	438	65.1	93.3	8/?/83	dis	EORSAT
Cosmos 1356	82-39A	May 5	PL	A-1	684	632	81.2	97.6			ELINT 1st generation
Cosmos 1357-1364	82-40A-H	May 6	PL	C-1	1520	1449	74	115.4			Tactical communications, octuple launch
Soyuz-T 5	82-42A	May 13	TT	A-2	326	261	51.6	90.3	8/27/82	106	Manned to Salyut 7, A Berezovoy & V Lebedev, docked 5/14-8/27/82
Cosmos 1365	82-43A	May 14	TT	F-1m	276	259	65	89.6			RORSAT, raised 9/27/82
					977	885	65.1	103.7*			
Cosmos 1366	82-44A	May 18	TT	D-1e		35820	1.5	1437			Geosync communications

						35834	35737	1.4	1435.9*			
Cosmos 1367	82-45A	May 20	PL	A-2e		39530	612	62.8	709			Early warning
						39770	585	62.8	717.8*			
Cosmos 1368	82-46A	May 21	TT	A-2		365	218	70.4	90	6/3/82	13	Photorecon, R
Progress 13	82-47A	May 23	TT	A-2		278	191	51.6	88.9	6/6/82	14	Freighter to Salyut 7, docked 5/25-6/4/82
Cosmos 1369	82-48A	May 25	PL	A-2		296	229	82.3	89.4	6/8/82	14	Photorecon/Earth resources, R
						276	269	82.3	89.9*			
Cosmos 1370	82-49A	May 28	TT	A-2		290	203	64.9	89.2	7/11/82	44	Photorecon, D
Molniya 1-54	82-50A	May 28	PL	A-2e		40633	653	62.8	736			Communications
						39720	635	62.8	717.8*			
Cosmos 1371	82-51A	Jun 1	PL	C-1		833	793	74.1	101			Store-dump communications
Cosmos 1372	82-52A	Jun 1	TT	F-1m		277	258	65	89.6			RORSAT, raised 8/11/82
						981	908	64.9	104.0*			
Cosmos 1373	82-53A	Jun 2	TT	A-2		368	217	70.4	90.1	6/16/82	14	Photorecon, R
						448	365	70.4	92.7*			
Cosmos 1374	82-54A	Jun 3	KY	C-1			225	50.7		6/3/82	<1	Sub-scale space plane, recovered in Indian Ocean
						222	167	50.7	88.3*			
Cosmos 1375	82-55A	Jun 6	PL	C-1		1021	990	65.9	105	10/21/85	dis	ASAT target, intercepted by Cosmos 1379
Cosmos 1376	82-56A	Jun 8	PL	A-2		274	227	82.3	89.2	6/22/82	14	Photorecon/Earth resources (Priroda), R
						274	261	82.3	89.9*			
Cosmos 1377	82-57A	Jun 8	TT	A-2		362	179	64.9	89.7	7/22/82	44	Photorecon, D
Cosmos 1378	82-59A	Jun 10	PL	F-2		682	648	82.5	97.8			ELINT 2nd generation
Cosmos 1379	82-60A	Jun 18	TT	F-1m		1027	552	65.8	100.3	6/18/82	<1	ASAT, intercepted Cosmos 1375 on 2nd rev
Cosmos 1380	82-61A	Jun 18	PL	C-1		732	156	82.9	93.1	6/27/82	9	Military navsat failure
Cosmos 1381	82-62A	Jun 18	TT	A-2		395	216	70.4	90.3	7/1/82	13	Photorecon, R
						450	362	70.4	92.7*			
Soyuz-T 6	82-63A	Jun 24	TT	A-2		277	248	51.6	89.6	7/2/82	8	Manned to Salyut 7, V Dzhanibekov, A Ivanchenkov & J-L Chretien (France), docked 6/25-7/2/82
Cosmos 1382	82-64A	Jun 25	PL	A-2e		39540	614	62.8	709			Early warning
						39747	609	62.8	717.8*			
Cosmos 1383	82-66A	Jun 29	PL	C-1		1041	1004	83	105.4			Civil navsat #11, COSPAS 1
Cosmos 1384	82-67A	Jun 30	PL	A-2		381	181	67.1	89.8	7/30/82	30	Photorecon, D
Cosmos 1385	82-68A	Jul 6	PL	A-2		264	197	82.3	88.7	7/20/82	14	Photorecon/Earth resources (Priroda), R
						389	307	82.3	91.6*			
Cosmos 1386	82-69A	Jul 7	PL	C-1		1010	965	83	104.6			Military navsat #2
Progress 14	82-70A	Jul 10	TT	A-2		258	192	51.6	88.7	8/13/82	34	Freighter to Salyut 7, docked 7/12-8/10/82
Cosmos 1387	82-71A	Jul 13	PL	A-2		271	219	82.3	89.1	7/26/82	13	Photorecon/Earth resources (Priroda), R
Cosmos 1388-1395	82-73A-H	Jul 21	PL	C-1		1515	1448	74	115.3			Tactical communications, octuple payload
Molniya 1-55	82-74A	Jul 21	TT	A-2e		38901	650	63	701			Communications
						39737	614	63.0	717.7*			
Cosmos 1396	82-75A	Jul 27	PL	A-2		323	208	72.9	89.5	8/10/82	14	Photorecon, R
						288	228	72.9	89.7*			
Cosmos 1397	82-76A	Jul 29	KY	C-1		549	346	50.7	93.4	5/18/83	293	Minor military
Cosmos 1398	82-77A	Aug 3	PL	A-2		262	225	82.3	89	8/13/82	10	Photorecon/geodesy, R
Cosmos 1399	82-78A	Aug 4	TT	A-2		371	179	64.9	89.7	9/16/82	43	Photorecon, D
Cosmos 1400	82-79A	Aug 5	PL	A-1		675	631	81.2	97.6			ELINT 1st generation
Soyuz-T 7	82-80A	Aug 19	TT	A-2		280	228	51.6	89.5	12/10/82	113	Manned to Salyut 7, L Popov, A Serebrov & Svetlana Savitskaya, docked 8/20-12/10/82
Cosmos 1401	82-81A	Aug 20	PL	A-2		282	226	82.3	89.3	9/3/82	14	Photorecon/Earth resources, R
						274	261	82.3	89.9*			
Molniya 3-19	82-83A	Aug 27	PL	A-2e		40814	494	62.8	736			Communications
						39856	498	62.9	717.8*			
Cosmos 1402	82-84A	Aug 30	TT	F-1m		279	254	65	89.6	1/23/83	146	RORSAT, reentered

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
Cosmos 1403	82-85A	Sep 1	TT	A-2	380	216	70.4	90.2	9/15/82	14	Photorecon, R
					416	354	70.4	92.3*			
Cosmos 1404	82-86A	Sep 1	PL	A-2	394	211	72.9	90.2	9/15/82	14	Photorecon, R
					416	358	72.9	92.3*			
Cosmos 1405	82-88A	Sep 4	TT	F-1m	456	438	65	93.3	2/5/84	519	EORSAT
Cosmos 1406	82-89A	Sep 8	PL	A-2	253	222	82.3	89	9/21/82	13	Photorecon/Earth resources (Priroda), R
					230	211	82.3	88.9*			
Cosmos 1407	82-91A	Sep 15	PL	A-2	364	181	67.2	89.7	10/16/82	31	Photorecon, D
Cosmos 1408	82-92A	Sep 16	PL	F-2	679	645	82.5	97.8			ELINT 2nd generation
Ekran 9	82-93A	Sep 16	TT	D-1e		35580	0.3	1426			Geosync DBS, Statsionar-T
					35827	35742	0.4	1435.9*			
Progress 15	82-94A	Sep 18	TT	A-2	258	195	51.6	88.7	10/16/82	28	Freighter to Salyut 7, docked 9/20-10/14/82
Cosmos 1409	82-95A	Sep 22	PL	A-2e	39340	613	62.8	709			Early warning
					39719	631	63.1	717.7*			
Cosmos 1410	82-96A	Sep 24	PL	F-2	1522	1500	82.6	116			Geodesy 2nd generation
Cosmos 1411	82-98A	Sep 30	PL	A-2	384	208	72.9	90.1	10/14/82	14	Photorecon, R
					287	229	72.8	89.7*			
Cosmos 1412	82-99A	Oct 2	TT	F-1m	280	255	65	89.6			RORSAT, raised 11/10/82
					983	909	64.8	104.0*			
Cosmos 1413-1415	82-100A,D,E	Oct 12	TT	D-1e		19100	64.8	673			GLONASS, Cosmos 1414 only stabilized
					19183	19077	64.8	675.7*			
Cosmos 1416	82-101A	Oct 12	TT	A-2	380	217	70.4	90.2	10/28/82	14	Photorecon, R
					278	231	70.4	89.6*			
Cosmos 1417	82-102A	Oct 19	PL	C-1	1023	978	83	104.9			Military navsat #6
Gorizont 6	82-103A	Oct 20	TT	D-1e		35800	0.8	1437			Geosync communications
					35812	35765	0.7	1436.1*			
Cosmos 1418	82-104A	Oct 21	KY	C-1	417	362	50.7	92.2	9/30/83	344	Minor military
Progress 16	82-107A	Oct 31	TT	A-2	263	193	51.6	88.7	12/14/82	44	Freighter to Salyut 7, docked 11/2-12/13/82
Cosmos 1419	82-108A	Nov 2	TT	A-2	290	216	70.4	89.3	11/16/82	14	Photorecon, R
					282	230	70.3	89.6*			
Cosmos 1420	82-109A	Nov 11	PL	C-1	820	782	74	100.8			Store-dump communications
Cosmos 1421	82-112A	Nov 18	TT	A-2	286	216	70.3	89.2	12/2/82	14	Photorecon, R
					282	231	70.3	89.6*			
Raduga 11	82-113A	Nov 26	TT	D-1e		36640	1.2	1480			Geosync communications
					35826	35753	132	1436.2*			
Cosmos 1422	82-114A	Dec 3	PL	A-2	314	208	73	89	12/17/82	14	Photorecon, R
					288	228	72.9	89.7*			
Cosmos 1423	82-115A	Dec 8	TT	A-2e	575	401	62.8	94.3	1/18/86	1137	Molniya failure
Meteor 2-9	82-116A	Dec 14	PL	A-1	904	836	81.3	102			Meteorology
Cosmos 1424	82-117A	Dec 16	TT	A-2	370	179.4	64.9	89.7	1/28/83	43	Photorecon, D
Cosmos 1425	82-119A	Dec 23	TT	A-2	374	237	70	90.3	1/6/83	14	Photorecon, R
					416	348	70.0	92.2*			
Cosmos 1426	82-120A	Dec 28	TT	A-2	377	209	50.6	90	3/5/83	67	Photorecon, 5th generation
Cosmos 1427	82-121A	Dec 29	PL	C-1	494	460	65.8	94			Minor military
1983											
Cosmos 1428	83-01A	Jan 12	PL	C-1	1017	972	82.9	104.7			Military navsat #3
Cosmos 1429-1436	83-02A-H	Jan 19	PL	C-1	1513	1449	74	115.3			Tactical communications, octuple launch
Cosmos 1437	83-03A	Jan 20	PL	A-1	678	629	81.2	97.6			ELINT 1st generation

Cosmos 1438	83-05A	Jan 27	TT	A-2	254	213	70.4	88.9	2/7/83	11	Photorecon, R
					344	167	70.4	89.6*			
Cosmos 1439	83-07A	Feb 6	TT	A-2	371	180	70.4	89.7	2/22/83	16	Photorecon , R
					251	170	70.4	88.7*			
Cosmos 1440	83-09A	Feb 10	PL	A-2	293	223	82.3	89.3	2/24/83	14	Photorecon/Earth resources, R
					275	260	82.3	89.9*			
Cosmos 1441	83-10A	Feb 16	PL	A-1	667	632	81	97.5			ELINT 1st generation
							81.1*				
Cosmos 1442	83-12A	Feb 25	PL	A-2	364	180	67.2	89.6	4/11/83	45	Photorecon, D
Cosmos 1443	83-13A	Mar 2	TT	D-1	269	199	51.6	88.9	9/19/83	201	Module to Salyut 7, docked 3/10-8/14/83
Cosmos 1444	83-14A	Mar 2	PL	A-2	413	203	72.9	90.3	3/16/83	14	Photorecon, R
					416	358	72.8	92.3*			
Molniya 3-20	83-15A	Mar 11	PL	A-2ö	40773	474	62.8	735			Communications
					39918	439	62.9	717.8*			
Ekran 10	83-16A	Mar 12	TT	D-1e		35619	0.1	1428			Geosync DBS, Statsionar-T
					35798	35778	0.2	1436.0*			
Cosmos 1445	83-17A	Mar 15	KY	C-1	217	176	50.7	88.4*	3/16/83	<1	Sub-scale space plane, recovered in Indian Ocean
Cosmos 1446	83-18A	Mar 16	TT	A-2	368	237	70	90.3	3/30/83	14	Photorecon, R
					239	227	69.9	89.2*			
Molniya 1-56	83-19A	Mar 16	PL	A-2e	40821	488	62.8	737			Communications
					39902	451	62.8	717.7*			
Astron	83-20A	Mar 23	TT	D-1e	200000	2000	51.5	5880			Science
Cosmos 1447	83-21A	Mar 24	PL	C-1	1025	975	83	104.9			Civil navsat #13, COSPAS 2
Cosmos 1448	83-23A	Mar 30	PL	C-1	1017	977	83	104.9			Military navsat #1
Cosmos 1449	83-24A	Mar 31	PL	A-2	402	207	72.9	90.3	4/15/83	15	Photorecon, R
					416	357	72.9	92.3*			
Molniya 1-57	83-25A	Apr 2	TT	A-2e	39023	483	62.9	700			Communications
					39863	492	63.0	717.8*			
Cosmos 1450	83-27A	Apr 6	PL	C-1	515	474	65.9	94.7			Minor military
Raduga 12	83-28A	Apr 8	TT	D-1e		35870	1.3	1440			Geosync communications
					35789	35782	1.2	1435.9*			
Cosmos 1451	83-29A	Apr 8	PL	A-2	264	194	82.3	88.7	4/22/83	14	Photorecon, R
					323	227	82.4	90.0*			
Cosmos 1452	83-31A	Apr 12	PL	C-1	826	786	74	100.8			Store-dump communications
Cosmos 1453	83-34A	Apr 19	PL	C-1	520	473	74	94.5			Minor military
Soyuz-T 8	83-35A	Apr 20	TT	A-2					4/22/83	2	Manned to Salyut 7, V Titov, G Strekalov & A Serebrov, failed to dock
					278	226	51.6	89.5*			
Cosmos 1454	83-36A	Apr 22	PL	A-2	374	181	67.2	89.7	5/22/83	30	Photorecon, D
Cosmos 1455	83-37A	Apr 23	PL	F-2	676	648	82.5	97.8			ELINT 2nd generation
Cosmos 1456	83-38A	Apr 25	PL	A-2e	39343	613	62.8	709			Early warning
					39716	622	63.0	717.4*			
Cosmos 1457	83-39A	pr 26	TT	A-2	376	180	70.4	89.8	6/8/83	43	Photorecon, D
Cosmos 1458	83-40A	Apr 28	PL	A-2	275	220	82.3	89.1	5/11/83	13	Photorecon/Earth resources (Priroda), R
					246	212	82.3	89.1*			
Cosmos 1459	83-42A	May 6	PL	C-1	1028	950	83	104.8			Military navsat #4
Cosmos 1460	83-43A	May 6	TT	A-2	369	218	70.3	90.1	5/20/83	14	Photorecon, R
					417	351	70.3	92.2*			
Cosmos 1461	83-44A	May 7	TT	F-1m	457	438	65	93.3	3/11/85	dis	EORSAT
Cosmos 1462	83-45A	May 17	PL	A-2	318	224	82.3	89.5	5/31/83	14	Photorecon/Earth resources (Priroda), R
					275	259	82.3	89.9*			
Cosmos 1463	83-46A	May 19	PL	C-1	1570	307	82.9	103.5			Minor military
Cosmos 1464	83-48A	May 24	PL	C-1	1022	985	82.9	104.9			Military navsat #5
Cosmos 1465	83-49A	May 26	KY	C-1	551	349	50.7	93.4	1/23/85	608	Minor military

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
Cosmos 1466	83-50A	May 26	TT	A-2	367	180	64.9	89.7	7/6/83	41	Photorecon, D
Cosmos 1467	83-52A	May 31	PL	A-2	389	209	72.9	90	6/12/83	12	Photorecon, R
					417	357	72.9	92.3*			
Venera 15	83-53A	Jun 2	TT	D-1e							Venus orbiter, arrived 10/10/83
					168	160	51.5	87.7*			
Venera 16	83-54A	Jun 7	TT	D-1e							Venus orbiter, arrived 10/14/83
					186	166	51.5	87.9*			
Cosmos 1468	83-55A	Jun 7	PL	A-2	283	227	82.3	89.3	6/21/83	14	Photorecon/Earth resources (Priroda) , R
					280	255	82.3	89.9*			
Cosmos 1469	83-57A	Jun 14	PL	A-2	377	211	72.8	90	6/24/83	10	Photorecon, R
Cosmos 1470	83-61A	Jun 23	PL	F-2	680	645	82.5	97.8			ELINT 2nd generation
Soyuz-T 9	83-62A	Jun 27	TT	A-2					11/23/83	149	Manned to Salyut 7, V Lyakhov & A Aleksandrov, docked 6/28-11/23/83
					304	260	51.6	90.1*			
Cosmos 1471	83-64A	Jun 28	PL	A-2	369	182	67.2	89.7	7/28/83	30	Photorecon, D
Gorizont 7	83-66A	Jul 1	TT	D-1e		36600	1.3	1479			Geosync communications
					35826	35745	1.4	1435.9*			
Prognoz 9	83-67A	Jul 1	TT	A-2e	720000	380	65.5	26.7d	7/?/83	<30	Science
Cosmos 1472	83-68A	Jul 5	PL	A-2	264	197	82.4	88.8	7/19/83	14	Photorecon/Earth resources, R
					362	338	82.4	91.6*			
Cosmos 1473-1480	83-69A-H	Jul 6	PL	C-1	1511	1448	74	115.1			Tactical communications, octuple launch
Cosmos 1481	83-70A	Jul 8	PL	A-2e	40165	615	62.8	718			Early warning
					39200	643	62.9	707.4*			
Cosmos 1482	83-71A	Jul 13	TT	A-2	376	217	70.0	90.2	7/27/83	14	Photorecon/Earth resources (Priroda), R
					413	352	70.0	92.2*			
Molniya 1-58	83-73A	Jul 19	TT	A-2e	39025	480	62.9	700			Communications
					39887	468	63.0	717.8*			
Cosmos 1483	83-74A	Jul 20	PL	A-2	305	277	82.3	89.5	8/3/83	14	Photorecon/Earth resources, R
					275	260	82.3	89.9*			
Cosmos 1484	83-75A	Jul 24	TT	A-1	673	595	98	97.3			Earth resources
Cosmos 1485	83-76A	Jul 26	PL	A-2	395	209	72.9	90.2	8/9/83	14	Photorecon, R
					416	358	72.9	92.3*			
Cosmos 1486	83-79A	Aug 3	PL	C-1	820	786	74.1	100.8			Store-dump communications
Cosmos 1487	83-80A	Aug 5	PL	A-2	305	226	82.3	89.5	8/19/83	14	Photorecon/Earth resources (Priroda), R
					275	261	82.3	89.9*			
Cosmos 1488	83-82A	Aug 9	PL	A-2	397	208	72.9	90.2	8/23/83	14	Photorecon, R
					416	358	72.9	92.3*			
Cosmos 1489	83-83A	Aug 10	TT	A-2	323	182	64.7	89.3	9/23/83	44	Photorecon, D
Cosmos 1490-1492	83-84A-C	Aug 10	TT	D-1e		19154	64.7	676			GLONASS, Cosmos 1490 and 1491 stabilized
					19171	19088	64.8	675.7*			
Progress 17	83-85A	Aug 17	TT	A-2	257	196	51.6	88.7	9/18/83	32	Freighter to Salyut 7, docked 8/19-9/17/83
Cosmos 1493	83-87A	Aug 23	PL	A-2	396	207	72.9	90.2	9/6/83	14	Photorecon, R
					414	360	72.9	92.3*			
Raduga 13	83-88A	Aug 25	TT	D-1e		36617	1.3	1478			Geosync communications
					35928	35649	1.3	1436.1*			
Molniya 3-21	83-90A	Aug 30	PL	A-2e	40815	497	62.8	736			Communications
					39890	464	62.9	717.8*			
Cosmos 1494	83-91A	Aug 31	KY	C-1	561	341	50.7	93.5	9/26/85	757	Minor military
Cosmos 1495	83-92A	Sep 3	PL	A-2	248	211	82.3	88.9	9/16/83	13	Photorecon/Earth resources, R
Cosmos 1496	83-93A	Sep 7	PL	A-2	335	173	67.2	89.6	10/19/83	42	Photorecon, D

Cosmos 1497	83-95A	Sep 9	PL	A-2	403	208	72.8	90.3	9/23/83	14	Photorecon, R
					416	357	72.9	92.3*			
Cosmos 1498	83-96A	Sep 14	PL	A-2	305	222	82.3	89.4	9/28/83	14	Photorecon/Earth resources, R
					275	261	82.3	89.9*			
Cosmos 1499	83-97A	Sep 17	PL	A-2	396	208	72.9	90.2	10/1/83	14	Photorecon, R
					416	357	72.9	92.3*			
Soyuz-T		Sep 26	TT	A-2							Launch abort, V Titov & G Strekalov
Cosmos 1500	83-99A	Sep 28	PL	F-2	679	649	82.6	97.8			Oceanography
Ekran 11	83-100A	Sep 29	TT	D-1e		36630	0.4	1428			Geosync DBS
					35796	35782	0.3	1436.1*			
Cosmos 1501	83-101A	Sep 30	PL	C-1	516	470	82.9	94.4			Minor military
Cosmos 1502	83-102A	Oct 5	PL	C-1	411	327	75.9	92.3	8/29/85	694	Minor military
							65.8*				
Cosmos 1503	83-103A	Oct 12	PL	C-1	827	791	74	100.9			Store-dump communications
Cosmos 1504	83-104A	Oct 14	TT	A-2	328	180	64.9	89.3	12/6/83	53	Photorecon, D
Vertikal 11		Oct 20	KY	C	500				10/20/83	<1	Geophysical probe, Intercosmos
Progress 18	83-106A	Oct 20	TT	A-2	269	193	51.6	88.8	11/16/83	27	Freighter to Salyut 7, docked 10/22-11/13/83
Cosmos 1505	83-107A	Oct 21	PL	A-2	377	210	72.9	90	11/4/83	14	Photorecon, R
					415	358	72.9	92.3*			
Cosmos 1506	83-108A	Oct 26	PL	C-1	1026	969	83	104.8			Civil navsat #12
Meteor 2-10	83-109A	Oct 28	PL	A-1	901	780	81.2	101			Meteorology
								101.4*			
Cosmos 1507	83-110A	Oct 29	TT	F-1m	449	431	65	93.02	8/19/87	1390	EORSAT
							65.1	93.3*			
Cosmos 1508	83-111A	Nov 11	PL	C-1	1964	400	83	108.8			Minor military
Cosmos 1509	83-112A	Nov 17	PL	A-2	309	209	72.9	89.3	12/1/83	14	Photorecon, R
					292	227	72.9	89.7*			
Molniya 1-59	83-114A	Nov 23	PL	A-2e	39150	465	62.8	702			Communications
					39875	476	62.8	717.7*			
Cosmos 1510	83-115A	Nov 24	PL	F-2	1537	1497	73.6	116.1			Geodesy 2nd generation
Cosmos 1511	83-117A	Nov 30	PL	A-2	368	181	67.2	89.7	1/13/84	44	Photorecon, D
Gorizont 8	83-118A	Nov 30	TT	D-1e		35850	1.4	1439			Geosync communications
					35968	35617	1.4	1436.3*			
Cosmos 1512	83-119A	Dec 7	PL	A-2	392	208	72.9	90.2	12/21/83	14	Photorecon, R
					418	356	72.9	92.3*			
Cosmos 1513	83-120A	Dec 8	PL	C-1	1029	977	83	105			Military navsat #6
Cosmos 1514	83-121A	Dec 14	PL	A-2	288	226	82.3	89.3	12/19/83	5	Biosatellite
Cosmos 1515	83-122A	Dec 15	PL	F-2	676	648	82.5	97.8			ELINT 2nd generation
Molniya 3-22	83-123A	Dec 21	PL	A-2e	40635	645	62.8	736			Communications
					39752	603	62.9	717.8*			
Cosmos 1516	83-124A	Dec 27	TT	A-2	299	205	65	89.2	2/9/84	44	Photorecon, D
Cosmos 1517	83-125A	Dec 27	KY	C-1					12/27/83	<1	Sub-scale space plane, recovered in Black Sea
					221	180	50.7	88.4*			
Cosmos 1518	83-126A	Dec28	PL	A-2e	39345	614	62.8	709			Early warning
					39725	622	63.0	717.6*			
Cosmos 1519-1521	83-127A-C	Dec 29	TT	D-1e		19100	64.3	674			GLONASS, Cosmos 1519 and 1520 stabilized
					19156	19104	64.8	675.7*			
1984											
Cosmos 1522-1529	84-01A-H	Jan 5	PL	C-1	1510	1449	74	115			Tactical communications, octuple launch
Cosmos 1530	84-02A	Jan 11	PL	A-2	391	206	72.8	90.1	1/25/84	14	Photorecon, R
					416	357	72.8	92.3*			
Cosmos 1531	84-03A	Jan 11	PL	C-1	1023	994	82.9	105			Military navsat #2

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
Cosmos 1532	84-04A	Jan 13	PL	A-2	382	178	67.2	89.8	2/26/84	44	Photorecon, D
Cosmos 1533	84-06A	Jan 26	TT	A-2	382	235	70.4	90.4	2/9/84	14	Photorecon, R
					416	349	70.4	92.2*			
Cosmos 1534	84-07A	Jan 26	PL	C-1	519	470	65.8	94.5			Minor military
Cosmos 1535	84-10A	Feb 2	PL	C-1	1029	974	83	105			Military navsat #3
Cosmos 1536	84-13A	Feb 8	PL	F-2	679	648	82.5	97.8			ELINT 2nd generation
Soyuz-T 10	84-14A	Feb 8	TT	A-2	274	226	51.6	89.4	4/11/84	63	Manned to Salyut 7, L Kizim, V Solovyev & O Atkov, docked 2/9/-4/11/84
Raduga 14	84-16A	Feb 15	TT	D-1e		35950	1.3	1440			Geosync communications
					35804	35766	1.2	1436.0*			
Cosmos 1537	84-17A	Feb 16	PL	A-2	317	220	82.4	89.5	3/1/84	14	Photorecon/Earth resources (Priroda), R
					274	261	82.4	89.9*			
Progress 19	84-18A	Feb 21	TT	A-2	261	192	51.6	88.7	4/1/84	41	Freighter to Salyut 7, docked 2/23-3/31/84
Cosmos 1538	84-19A	Feb 21	PL	C-1	820	781	74	100.8			Store-dump communications
Cosmos 1539	84-20A	Feb 28	PL	A-2	367	179	67.1	89.6	4/9/84	41	Photorecon, D
Cosmos 1540	84-22A	Mar 2	TT	D-1e		36000	1.4	1445			Geosync communications
					35825	35729	1.4	1435.6*			
Cosmos 1541	84-24A	Mar 6	PL	A-2e	39424	584	62.9	710			Early warning
					39750	600	62.9	717.7*			
Cosmos 1542	84-25A	Mar 7	TT	A-2	373	236	70.4	90.3	3/21/84	14	Photorecon, R
					416	350	70.4	92.2*			
Cosmos 1543	84-26A	Mar 10	PL	A-2	416	224	62.8	90.6	4/5/84	26	Photorecon, 5th generation, D
Cosmos 1544	84-27A	Mar 15	PL	F-2	677	649	82.5	97.8			ELINT 2nd generation
Ekran 12	84-28A	Mar 16	TT	D-1e		35530	0.1	1423			Geosync DBS
					35837	35739	0.2	1436.1*			
Molniya 1-60	84-29A	Mar 16	PL	A-2e	40579	646	62.9	735			Communications
					39737	618	62.9	717.8*			
Cosmos 1545	84-30A	Mar 21	PL	A-2	396	208	72.9	90.2	4/5/84	15	Photorecon, R
					415	356	72.8	92.3*			
Cosmos 1546	84-31A	Mar 29	TT	D-1e		36029	1.3	1448			Geosync communications?
					35799	35781	1.1	1436.2*			
Soyuz-T 11	84-32A	Apr 3	TT	A-2	275	222	51.6	89.4	10/2/84	182	Manned to Salyut 7, Y Malyshev, G Strekalov & R Sharma (India), docked 4/4-10/2/84
Cosmos 1547	84-33A	Apr 4	PL	A-2e	39340	615	62.8	709			Early warning
					39749	597	62.8	717.6*			
Cosmos 1548	84-36A	Apr 10	PL	A-2	359	177	67.1	89.5	6/25/84	45	Photorecon, D
Progress 20	84-38A	Apr 15	TT	A-2	277	192	51.6	88.9	5/7/84	22	Freighter to Salyut 7, docked 4/17-5/6/84
Cosmos 1549	84-40A	Apr 19	PL	A-2	394	208	72.9	90.2	5/3/84	14	Photorecon, R
					415	359	72.9	92.3*			
Gorizont 9	84-41A	Apr 22	TT	D-1m		36320	11.5	1463			Geosync communications; TASS inclination is obviously a typographical error
					35786	35784	1.5	1436.0*			
Progress 21	84-42A	May 7	TT	A-2	264	192	51.6	88.7	5/26/84	19	Freighter to Salyut 7, docked 5/10-5/26/84
Cosmos 1550	84-43A	May 11	PL	C-1	1025	993	83	105			Military navsat failure?
Cosmos 1551	84-44A	May 11	PL	A-2	305	209	72.9	89.3	5/23/84	12	Photorecon, R
					259	212	72.9	89.2*			
Cosmos 1552	84-45A	May 14	TT	A-2	344	191	64.9	89.6	11/3/84	173	Photorecon, 5th generation, D
Cosmos 1553	84-46A	May 17	PL	C-1	1020	977	82.9	104.8			Military navsat #1
Cosmos 1554-1556	84-47A-C	May 19	TT	D-1e		19125	64.8	676			GLONASS, Cosmos 1554 and 1555 stabilized
					19180	19080	64.8	675.7*			
Cosmos 1557	84-48A	May 22	PL	A-2	276	221	82.3	89.2	6/4/84	13	Photorecon/Earth resources (Priroda), R

Cosmos 1558	84-50A	May 25	PL	A-2	249	213	82.3	89.2°						
Progress 22	84-51A	May 28	TT	A-2	318	178	67.2	89.1	7/8/84	44	Photorecon, D
Cosmos 1559-1566	84-52A-H	May 28	PL	C-1	261	194	51.6	88.8	7/15/84	48	Freighter to Salyut 7, docked 5/30-7/15/84
Cosmos 1567	84-53A	May 30	TT	F-1m	1512	1444	74	115			Tactical communications, octuple launch
Cosmos 1568	84-54A	Jun 1	PL	A-2	462	428	65	93.3	4/3/88	1404	EORSAT
					396	209	72.8	90.2	6/14/84	13	Photorecon, R
Cosmos 1569	84-55A	Jun 6	PL	A-2e	416	357	72.8	92.3°			
					40165	614	62.8	710			Early warning
Cosmos 1570	84-56A	Jun 8	PL	C-1	39762	589	62.9	717.7°			
Cosmos 1571	84-58A	Jun 11	TT	A-2	830	792	74	100.9			Store-dump communications
					398	218	70.0	90.4	6/26/84	15	Photorecon, R
Cosmos 1572	84-60A	Jun 15	PL	A-2	416	348	70.0	92.2°			
					297	227	82.4	89.4	6/29/84	14	Photorecon/Earth resources (Priroda), R
Cosmos 1573	84-61A	Jun 19	PL	A-2	275	261	82.4	89.9°			
					317	209	72.9	89.4	6/28/84	9	Photorecon, R
Cosmos 1574	84-62A	Jun 21	PL	C-1	310	232	72.9	89.9°			
Raduga 15	84-63A	Jun 22	TT	D-1e	1021	985	83	105			Civil navsat #14, COSPAS 3
						35100	1.3	1397			Geosync communications
Cosmos 1575	84-64A	Jun 22	PL	A-2	35809	35757	1.2	1435.8°			
					292	231	82.3	89.4	7/7/84	15	Photorecon/Earth resources (Priroda), R
Cosmos 1576	84-66A	Jun 26	PL	A-2	277	259	82.3	89.9°			
Cosmos 1577	84-67A	Jun 27	PL	C-1	376	180	67.1	89.7	8/24/84	59	Photorecon, D
Cosmos 1578	84-68A	Jun 28	KY	C-1	1023	974	83	104.9			Military navsat #5
Cosmos 1579	84-69A	Jun 29	TT	F-1m	1673	276	50.7	105			Minor military
					281	257	65	89.6			RORSAT, raised 9/27/84
Cosmos 1580	84-70A	Jun 29	PL	A-2	987	902	65.1	104.0°			
					367	249	62.8	90.4	7/13/84	14	Photorecon, R
Cosmos 1581	84-71A	Jul 3	PL	A-2e	271	229	62.8	89.5°			
					40165	614	62.8	710			Early warning
Meteor 2-11	84-72A	Jul 5	PL	F-2	39720	626	63.0	717.6°			
Soyuz-T 12	84-73A	Jul 17	TT	A-2	974	954	82.5	104			Meteorology
					309	282	51.6	90.2	7/29/84	12	Manned to Salyut 7, V Dzhanibekov, Svetlana Savitskaya & I Volk, docked 7/18-7/29/84
Cosmos 1582	84-74A	Jul 19	PL	A-2	308	227	82.4	89.5	8/2/84	14	Photorecon/Earth resources (Priroda), R
					281	255	82.4	89.9°			
Cosmos 1583	84-75A	Jul 24	PL	A-2	388	209	72.9	90.1	8/8/84	15	Photorecon, R
					416	357	72.9	92.3°			
Cosmos 1584	84-76A	Jul 27	PL	A-2	268	193	82.4	88.8	8/10/84	14	Photorecon/Earth resources, R
					366	182	82.3	90.0°			
Cosmos 1585	84-77A	Jul 31	TT	A-2	324	181	64.8	89.3	9/28/84	59	Photorecon, D
Gorizont 10	84-78A	Aug 1	TT	D-1e		35785	1.4	1435			Geosync communications
					35824	35748	1.4	1435.9°			
Cosmos 1586	84-79A	Aug 2	PL	A-2e	40165	614	62.8	710			Early warning
					39739	609	63.0	717.6°			
Cosmos 1587	84-82A	Aug 6	PL	A-2	394	209	72.9	90.2	8/31/84	25	Combined photorecon, R
					367	197	72.9	90.2°			
					415	357	72.9	92.3°			
Cosmos 1588	84-83A	Aug 7	TT	F-1m	457	438	65	93.3	2/23/86	dis	EORSAT
Cosmos 1589	84-84A	Aug 8	PL	F-2	1523	1500	82.6	116			Geodesy 2nd generation
Molniya 1-61	84-85A	Aug 10	PL	A-2e	40772	609	62.7	735			Communications
					39745	609	62.9	717.8°			
Progress 23	84-86A	Aug 14	TT	A-2	267	194	51.6	88.8	8/28/84	14	Freighter to Salyut 7, docked 8/16-8/26/84
Cosmos 1590	84-87A	Aug 16	PL	A-2	293	221	82.4	89.3	8/30/84	14	Photorecon/Earth resources (Priroda), R

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
					273	263	82.4	89.9°			
Molniya 1-62	84-89A	Aug 24	PL	A-2e	40877	467	62.8	737			Communications
					39900	455	62.8	717.8°			
Ekran 13	84-90A	Aug 24	TT	D-1e		35580	0.4	1425			Geosync DBS, Statsionar-T
					35801	35775	0.4	1436.2°			
Cosmos 1591	84-92A	Aug 30	PL	A-2	300	220	82.3	89.4	9/13/84	14	Photorecon/Earth resources (Priroda), R
					274	262	82.3	89.9°			
Cosmos 1592	84-94A	Sep 4	PL	A-2	380	209	72.9	90	9/18/84	14	Photorecon, R
					290	226	72.9	89.7°			
Cosmos 1593-1595	84-95A-C	Sep 4	TT	D-1e		19141	64.7	676			GLONASS, Cosmos 1593 and 1595 stabilized
				1595	19171	19089	64.8	675.7°			
Cosmos 1596	84-96A	Sep 7	PL	A-2e	39342	613	62.8	709			Early warning
					39725	615	63.0	717.5°			
Cosmos 1597	84-99A	Sep 13	PL	A-2	272	219	82.3	89.1	9/26/84	13	Photorecon/Earth resources, R
					246	213	82.3	89.1°			
Cosmos 1598	84-100A	Sep 13	PL	C-1	1029	987	83	105.2			Military navsat #3
Cosmos 1599	84-102A	Sep 25	PL	A-2	275	179	67.2	88.7	11/20/84	56	Photorecon, D
Cosmos 1600	84-103A	Sep 27	TT	A-2	404	215	70.0	90.4	10/11/84	14	Photorecon, R
					417	349	70.0	92.2°			
Cosmos 1601	84-104A	Sep 27	PL	C-1	521	477	65.8	94.5			Minor military
Cosmos 1602	84-105A	Sep 28	PL	F-2	680	648	82.5	97.8			Oceanography
Cosmos 1603	84-106A	Sep 28	TT	D-1e	877	852	71.2	102.2			ELINT 3rd generation
Cosmos 1604	84-107A	Oct 4	PL	A-2e	39342	613	62.8	709			Early warning
					39720	604	62.9	717.1°			
Cosmos 1605	84-109A	Oct 11	PL	C-1	1031	969	82.9	104.9			Military navsat #4
Cosmos 1606	84-111A	Oct 18	PL	F-2	678	649	82.5	97.7			ELINT 2nd generation
Cosmos 1607	84-112A	Oct 31	TT	F-1m	280	256	65	89.6			RORSAT, raised 2/1/85
					997	909	65.0	104.1°			
Cosmos 1608	84-116A	Nov 14	TT	A-2	275	205	70	89	12/17/84	33	Photorecon, 5th generation
Cosmos 1609	84-117A	Nov 14	PL	A-2	385	208	73	90	11/28/84	14	Photorecon, R
					415	358	72.9	92.3°			
Cosmos 1610	84-118A	Nov 15	PL	C-1	1027	987	83	105			Military navsat #2
Cosmos 1611	84-119A	Nov 21	TT	A-2	326	181	64.8	89.3	1/11/85	51	Photorecon, D
Cosmos 1612	84-120A	Nov 27	PL	F-2	1231	130	82.6	98.1	1/31/85	65	Meteor-3 failure
Cosmos 1613	84-121A	Nov 29	PL	A-2	382	209	72.8	90	12/24/84	25	Combined photorecon, R
					356	198	72.8	90.1°			
					416	356	72.8	92.3°			
Molniya 1-63	84-124A	Dec 14	PL	A-2e	40900	461	62.8	737			Communications
					39902	456	62.9	717.8°			
Vega 1	84-125A	Dec 15	TT	D-1e							Flew by Venus 6/10/85 and Comet Halley 3/6/86
					210	173	51.6	88.3°			
Cosmos 1614	84-126A	Dec 19	KY	C-1					12/19/84	<1	Sub-scale space plane, recovered in Black Sea
					223	173	50.7	88.4°			
Cosmos 1615	84-127A	Dec 20	PL	C-1	501	437	65.9	93.9			Minor military
Vega 2	84-128A	Dec 21	TT	D-1e							Flew by Venus 6/14/85 and Comet Halley 3/9/86
					217	178	51.6	88.4°			
1985											
Cosmos 1616	85-02A	Jan 9	TT	A-2	381	180	64.9	89.8	3/4/85	54	Photorecon, D

Cosmos 1617–1622	85–03A–F	Jan 15	PL	F–2	1438	1400	82.6		114					Sextuple launch
Molniya 3–23	85–04A	Jan 16	PL	A–2e	40653	646	62.9		736					Communications
					39755	628	62.9		718.3*					
Cosmos 1623	85–05A	Jan 16	TT	A–2	405	216	70		90.4	1/30/85	14			Photorecon, R
					415	349	70.0		92.2*					
Cosmos 1624	85–06A	Jan 17	PL	C–1	825	787	74		100.8					Store–dump communications
Gorizont 11	85–07A	Jan 18	TT	D–1e		35096	1.5		1401					Geosync communications
					35815	35748	1.5		1435.7*					
Cosmos 1625	85–08A	Jan 23	TT	F–1m	411	114	65		89.7	1/25/85	2			EORSAT failure
Cosmos 1626	85–09A	Jan 24	PL	F–2	677	643	82.5		97.7					ELINT 2nd generation
Cosmos 1627	85–11A	Feb 1	PL	C–1	1031	977	82.9		104.9					Military navsat #1
Cosmos 1628	85–12A	Feb 6	PL	A–2	407	206	72.8		90.3	2/20/85	14			Photorecon, R
					415	355	72.9		92.3*					
Meteor 2–12	85–13A	Feb 6	PL	F–2	975	950	82.5		104					Meteorology
Cosmos 1629	85–16A	Feb 21	TT	D–1e		36157	1.3		1453					Geosync communications?
					35793	35773	0.9		1435.8*					
Cosmos 1630	85–17A	Feb 27	TT	A–2	357	182	64.9		89.6	4/23/85	55			Photorecon, D
Cosmos 1631	85–18A	Feb 27	PL	C–1	517	474	65.9		94.5					Minor military
Cosmos 1632	85–19A	Mar 1	PL	A–2	261	203	72.9		88.8	3/15/85	14			Photorecon, R
					267	209	72.9		89.3*					
Cosmos 1633	85–20A	Mar 5	PL	F–2	671	641	82.5		97.7					ELINT 2nd generation
Cosmos 1634	85–22A	Mar 14	PL	C–1	1024	976	82.9		104.7					Military navsat #6
Cosmos 1635–1642	85–23A–H	Mar 21	PL	C–1	1526	1482	74		116					Tactical communications, octuple launch
Ekran 14	85–24A	Mar 22	TT	D–1e		35600	0.4		1426					Geosync DBS
					35800	35775	0.3		1436.0*					
Cosmos 1643	85–26A	Mar 25	TT	A–2	300	190	64.8		89.1	10/18/85	207			Photorecon, 5th generation, D
					294	223	64.8		89.7*					
Cosmos 1644	85–27A	Apr 3	TT	A–2	398	217	70.4		90.4	4/17/85	14			Photorecon, R
					415	349	70.4		92.2*					
Cosmos 1645	85–29A	Apr 16	PL	A–2	411	223	62.8		90.5	4/29/85	13			Microgravity materials processing
Cosmos 1646	85–30A	Apr 18	TT	F–1m	45	435	65		93.3	12/?/87	dis			EORSAT
Cosmos 1647	85–31A	Apr 19	PL	A–2	348	180	67.1		89.4	6/11/85	53			Photorecon, D
Cosmos 1648	85–32A	Apr 25	PL	A–2	265	196	82.3		88.8	5/6/85	11			Photorecon, R
Prognoz 10	85–33A	Apr 26	TT	A–2e	200000	420	65	96h	25m					Science [Intercosmos 23]
Cosmos 1649	85–36A	May 15	PL	A–2	396	208	72.9		90.2	5/29/85	14			Photorecon, R
					415	356	72.9		92.3*					
Cosmos 1650–1652	85–37A–C	May 17	TT	D–1e		19137	64.8		676					GLONASS, Cosmos 1651 and 1652 stabilized
					19175	19085	64.8		675.7*					
Cosmos 1653	85–38A	May 22	PL	A–2	322	222	82.3		89.6	6/5/85	14			Photorecon/Earth resources, R
					273	259	82.3		89.9*					
Cosmos 1654	85–39A	May 23	TT	A–2	356	180	64.9		89.7	6/21/85	dis			Photorecon, 5th generation
Molniya 3–24	85–40A	May 29	PL	A–2e	40850	465	62.8		736					Communications
					39852	503	62.8		717.8*					
Cosmos 1655	85–41A	May 30	PL	C–1	1019	992	82.9		104.9					Civil navsat #13
Cosmos 1656	85–42A	May 30	TT	D–1e	864	811	71.1		101.6					ELINT 3rd generation
Soyuz–T 13	85–43A	Jun 6	TT	A–2	338	304	51.6		90.8	9/26/85	112			Manned to Salyut 7, V Dzhanibekov & V Savinykh, docked 6/8–9/25/85
Cosmos 1657	85–44A	Jun 7	PL	A–2	313	195	82.3		89.2	6/21/85	14			Photorecon/Earth resources, R
					274	258	82.3		89.9*					
Cosmos 1658	85–45A	Jun 11	PL	A–2e	39342	613	62.8		709					Early warning
					39734	588	62.9		717.3*					
Cosmos 1659	85–46A	Jun 13	PL	A–2	379	210	72.9		90.1	6/27/85	14			Photorecon, R
					415	357	72.9		92.3*					
Cosmos 1660	85–47A	Jun 14	PL	F–2	1538	1499	73.6		116					Geodesy 2nd generation

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
Cosmos 1661	85-49A	Jun 18	PL	A-2e	40164	613	62.8	726			Early warning
					39742	609	63.0	717.7*			
Cosmos 1662	85-50A	Jun 19	PL	C-1	521	478	65.9	94.5			Minor military
Progress 24	85-51A	Jun 21	TT	A-2	270	193	51.6	88.8	7/15/85	25	Freighter to Salyut 7, docked 6/23-7/15/85
Cosmos 1663	85-52A	Jun 21	PL	A-2	298	227	82.3	89.4	7/5/85	14	Photorecon/Earth resources (Priroda), R
Unannounced	85-53A-C	Jun 21	TT	J-1	273	259	82.3	89.9*			
					340	197	64.4	89.9*	7/?/85		Engineering test
Cosmos 1664	85-54A	Jun 26	PL	A-2	405	207	72.9	90.3	7/5/85	9	Photorecon, R
					379	224	72.8	90.6*			
Cosmos 1665	85-57A	Jul 3	PL	A-2	316	208	72.9	89.4	7/17/85	14	Photorecon, R
Cosmos 1666	85-58A	Jul 8	PL	F-2	679	646	82.5	97.8			ELINT 2nd generation
Cosmos 1667	85-59A	Jul 10	PL	A-2	287	222	82.3	89	7/17/85	7	Biosatellite
Cosmos 1668	85-60A	Jul 15	TT	A-2	297	216	70.4	89.3	7/29/85	14	Photorecon, R
Molniya 3-25	85-61A	Jul 17	PL	A-2e	40850	462	62.8	736			Communications
Cosmos 1669	85-62A	Jul 19	TT	A-2	264	193	51.6	88.8	8/30/85	41	Freighter to Salyut 7, docked 7/21-8/29/85
Cosmos 1670	85-64A	Aug 1	TT	F-1m	278	253	65	89.6			RORSAT, raised 10/22/85
					989	898	64.7	103.9*			
Cosmos 1671	85-65A	Aug 2	PL	A-2	310	210	72.8	89.3	8/16/85	14	Photorecon, R
					258	228	72.9	89.4*			
Cosmos 1672	85-67A	Aug 7	PL	A-2	290	199	82.3	89	8/21/85	14	Photorecon/Earth resources, R
					273	258	82.3	89.9*			
Cosmos 1673	85-68A	Aug 8	TT	A-2	294	204	64.8	89.2	9/19/85	42	Photorecon, D
Cosmos 1674	85-69A	Aug 8	PL	F-2	677	648	82.5	97.8			ELINT 2nd generation
Raduga 16	85-70A	Aug 8	TT	D-1e		36560	1.3	1476			Geosync communications
					35832	35739	1.3	1436.0*			
Cosmos 1675	85-71A	Aug 12	PL	A-2e	39342	613	62.8	709			Early warning
					39729	596	62.8	717.2*			
Cosmos 1676	85-72A	Aug 16	PL	A-2	371	178	67.2	89.7	10/14/85	59	Photorecon, D
Molniya 1-64	85-74A	Aug 22	PL	A-2e	40638	656	62.8	736			Communications
					39696	657	62.9	717.7*			
Cosmos 1677	85-75A	Aug 23	TT	F-1m	280	255	65	89.6			RORSAT, raised 10/23/85
					987	917	64.9	104.1*			
Cosmos 1678	85-77A	Aug 29	PL	A-2	311	196	82.3	89.2	9/12/85	14	Photorecon/Earth resources (Priroda), R
					273	258	82.3	90.0*			
Cosmos 1679	85-78A	Aug 29	TT	A-2	364	182	64.9	89.7	10/18/85	50	Photorecon, D
Cosmos 1680	85-79A	Sep 4	PL	C-1	822	787	74.1	100.8			Store-dump communications
Cosmos 1681	85-80A	Sep 6	PL	A-2	261	216	82.4	89	9/19/85	13	Photorecon/Earth resources (Priroda), R
					227	219	82.3	89.0*			
Soyuz-T 14	85-81A	Sep 17	TT	A-2	325	274			11/21/85	65	Manned to Salyut 7, V Vasyutin, G Grechko & A Volkov, docked 9/18-11/21/85
							51.6	90.4*			
Cosmos 1682	85-82A	Sep 19	TT	F-1m	454	435	65	93.3	12/18/86	dis	EORSAT
Cosmos 1683	85-83A	Sep 19	PL	A-2	399	208	72.9	90.2	10/4/85	15	Photorecon, R
					414	356	72.9	92.3*			
Cosmos 1684	85-84A	Sep 24	PL	A-2e	39342	613	62.8	709			Early warning
					39762	580	62.9	717.5*			
Cosmos 1685	85-85A	Sep 26	PL	A-2	379	209	72.9	90	10/10/85	14	Photorecon, R
					415	356	72.9	92.3*			

Cosmos 1686	85-86A	Sep 27	TT	D-1	320	178	51.6	89.2				Module to Salyut 7, docked 10/2/85
Cosmos 1687	85-88A	Sep 30	PL	A-2e	39342	613	62.8	709				Early warning
					39717	635	63.0	717.7*				
Cosmos 1688	85-89A	Oct 2	KY	C-1	555	347	50.7	93.4				Minor military
Cosmos 1689	85-90A	Oct 3	TT	A-1	663	574	98	97				Earth resources
Molniya 3-26	85-91A	Oct 3	PL	A-2e	40605	644	62.9	735				Communications
					39738	609	62.9	717.6*				
Cosmos 1690-1695	85-94A-F	Oct 9	PL	F-2	1439	1400	82.6	114				Sextuple launch; Cosmos 1691 disintegrated 11/22/85
Cosmos 1696	85-95A	Oct 16	TT	A-2	298	216	70.4	89.3	10/30/85	14		Photorecon, R
					281	230	70.4	89.7*				
Cosmos 1697	85-97A	Oct 22	TT	J-1	880	852	71	102				ELINT 3rd generation
Cosmos 1698	85-98A	Oct 22	PL	A-2e	39342	613	62.8	709				Early warning
					39725	603	62.9	717.2*				
Molniya 1-65	85-99A	Oct 23	TT	A-2e	38845	658	63	700				Communications
					39731	631	63.0	717.9*				
Meteor 3-01	85-100A	Oct 24	PL	F-2	1263	1235	82.5	110.3				Meteorology, 3rd generation
Cosmos 1699	85-101A	Oct 25	PL	A-2	364	177	67.3	89.6	12/23/85	59		Photorecon, D
Cosmos 1700	85-102A	Oct 25	TT	D-1e		35760	1.4	1431				Geosync data-relay
					35810	35758	1.4	1435.9*				
Molniya 1-66	85-103A	Oct 28	PL	A-2e	39145	480	62.8	702				Communications
					39857	508	62.8	718.0*				
Cosmos 1701	85-105A	Nov 9	PL	A-2e	39342	613	62.8	709				Early warning
					39710	632	63.1	717.5*				
Cosmos 1702	85-106A	Nov 13	PL	A-2	399	207	72.8	90.2	11/27/85	14		Photorecon, R
					414	356	72.9	92.3*				
Raduga 17	85-107A	Nov 15	TT	D-1e		36655	1.3	1481				Geosync communications
					35795	35792	1.3	1436.3*				
Cosmos 1703	85-108A	Nov 22	PL	F-2	678	647	82.5	97.8				ELINT 2nd generation
Cosmos 1704	85-110A	Nov 28	PL	C-1	1123	986	82.9	105				Military navsat #3
Cosmos 1705	85-111A	Dec 3	PL	A-2	387	208	72.8	90.1	12/17/85	14		Photorecon, R
					415	356	72.9	92.3*				
Cosmos 1706	85-112A	Dec 11	PL	A-2	360	178	67.2	89.5	2/9/86	60		Photorecon, D
Cosmos 1707	85-113A	Dec 12	PL	F-2	678	650	82.5	97.8				ELINT 2nd generation
Cosmos 1708	85-115A	Dec 13	PL	A-2	313	197	82.3	89.2	12/27/85	14		Photorecon/Earth resources (Priroda), R
					273	256	82.3	90.0*				
Cosmos 1709	85-116A	Dec 19	PL	C-1	1026	982	82.9	104.9				Military navsat #2
Molniya 3-27	85-117A	Dec 24	PL	A-2e	40793	477	62.8	736				Communications
					39857	490	62.9	717.6*				
Cosmos 1710-1712	85-118A-C	Dec 24	TT	D-1e		19160	65	677				GLONASS, Cosmos 1710 & 1711 stabilized
					19147	19112	64.8	675.7*				
Meteor 2-13	85-119A	Dec 26	PL	F-2	975	952	82.5	104				Meteorology
Cosmos 1713	85-120A	Dec 27	PL	A-2	419	224	62.8	90.7	1/22/86	26		Photorecon, D
Cosmos 1714	85-121A	Dec 28	TT	J-1	863	190	71	94.8	2/27/86	61		ELINT 3rd generation failure
1986												
Cosmos 1715	86-01A	Jan 8	PL	A-2	317	207	72.8	89.4	1/22/86	14		Photorecon, R
					283	227	72.8	89.6*				
Cosmos 1716-1723	86-02A-H	Jan 9	PL	C-1	1516	1447	74	115				Tactical communications, octuple launch
Cosmos 1724	86-04A	Jan 15	PL	A-2	358	179	67.2	89.5	3/15/86	59		Photorecon, D
Cosmos 1725	86-05A	Jan 16	PL	C-1	1016	989	82.9	104.9				Military navsat #5
Cosmos 1726	86-06A	Jan 17	PL	F-2	676	649	82.5	97.7				ELINT 2nd generation
Raduga 18	86-07A	Jan 17	TT	D-1e		36578	1.2	1476				Geosync communications
					35783	35779	1.3	1435.7*				

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
Cosmos 1727	86-08A	Jan 23	PL	C-1	1029	982	82.6	104.9			Civil navsat #12
							83.0*				
Cosmos 1728	86-09A	Jan 28	TT	A-2	305	214	70	89.4	2/11/86	14	Photorecon, R
Cosmos 1729	86-11A	Feb 1	PL	A-2e	39342	614	62.8	709			Early warning
					39733	633	62.9	718.0*			
Cosmos 1730	86-12A	Feb 4	PL	A-2	333	206	72.9	89.5	2/13/86	9	Photorecon, R
Cosmos 1731	86-13A	Feb 7	TT	A-2	291	191	65	89	10/3/86	238	Photorecon, 5th generation, D
Cosmos 1732	86-15A	Feb 11	PL	F-2	1538	1497	73.6	116			Geodesy 2nd generation
Mir	86-17A	Feb 19	TT	D-1							Space station
					340	324	51.6	91.1*			
Cosmos 1733	86-18A	Feb 19	PL	F-2	674	643	82.5	97.4			ELINT 2nd generation
Cosmos 1734	86-20A	Feb 26	PL	A-2	371	176	67.1	89.6	4/26/86	59	Photorecon, D
Cosmos 1735	86-21A	Feb 27	TT	F-1m	440	416	65	92.8			EORSAT
Soyuz-T 15	86-22A	Mar 13	TT	A-2	298	240	51.6	89.7	7/16/86	125	Manned, L Kizim & V Solovyev, to Mir, docked 3/15-5/5 and Salyut 7 docked 5/6-6/25, and back to Mir, docked 6/26-7/16/86
Progress 25	86-23A	Mar 19	TT	A-2	268	189	51.6	88.8	4/21/86	33	Freighter to Mir, docked 3/21-4/20/86
Cosmos 1736	86-24A	Mar 21	TT	F-1m	278	255	65	89.6			RORSAT, raised 6/21/86
					1012	925	65.0	104.5*			
Cosmos 1737	86-25A	Mar 25	TT	F-1m	442	230	73	91	12/3/86	253	EORSAT, D
					431	416	73.4	93.1*			
Cosmos 1738	86-27A	Apr 4	TT	D-1e		36560	1.4	1477			Geosync communications
					35824	35747	1.4	1435.9*			
Cosmos 1739	86-28A	Apr 9	TT	A-2	352	182	64.9	89.5	6/7/86	59	Photorecon, D
Cosmos 1740	86-29A	Apr 15	PL	A-2	396	208	72.9	90.2	4/28/86	13	Photorecon, R
					416	355	72.9	92.3*			
Cosmos 1741	86-30A	Apr 17	PL	C-1	824	784	74	100.8			Store-dump communications
Molniya 3-28	86-31A	Apr 18	PL	A-2e	40664	638	62.9	736			Communications
					39739	613	62.8	717.7*			
Progress 26	86-32A	Apr 23	TT	A-2	274	190	51.6	88.8	6/23/86	61	Freighter to Mir, docked 4/26-6/23/86
Cosmos 1742	86-33A	May 14	PL	A-2	388	209	73	90.1	5/28/86	14	Photorecon, R
					419	353	72.9	92.3*			
Cosmos 1743	86-34A	May 15	PL	F-2	678	657	82.6	97.8			ELINT 2nd generation
Soyuz-TM 1	86-35A	May 21	TT	A-2	240	200	51.6	88.6	5/30/86	9	Unmanned to Mir, docked 5/23-5/29/86
Cosmos 1744	86-36A	May 21	PL	A-2	395	227	62.8	90.4	6/4/86	14	Microgravity materials processing
Cosmos 1745	86-37A	May 23	PL	C-1	1024	984	83	104.9			Military navsat #1
Ekran 15	86-38A	May 24	TT	D-1e		35500	0.3	1426			Geosync DBS
					35810	35771	0.4	1436.2*			
Meteor 2-14	86-39A	May 27	PL	F-2	974	953	82.5	104.1			Meteorology
Cosmos 1746	86-40A	May 28	PL	A-2	308	195	82.3	89.2	6/11/86	14	Photorecon/Earth resources (Priroda), R
					273	259	82.3	89.9*			
Cosmos 1747	86-41A	May 29	TT	A-2	420	217	70.4	09.6	6/12/86	14	Photorecon, R
					255	211	70.4	89.2*			
Cosmos 1748-1755	86-42A-H	Jun 6	PL	C-1	1506	1444	74	115.1			Tactical communications, octuple launch
Cosmos 1756	86-43A	Jun 6	TT	A-2	368	182	64.9	89.7	8/4/86	59	Photorecon, D
Gorizont 12	86-44A	Jun 10	TT	D-1e		36540	1.5	1414			Geosync communications
					35834	35735	1.3	1435.9*			
Cosmos 1757	86-45A	Jun 11	PL	A-2	252	189	82.3	88.6	6/25/86	14	Photorecon/Earth resources (Priroda), R
					391	159	82.3	90.1*			
Cosmos 1758	86-46A	Jun 12	PL	F-2	682	644	82.5	97.8			ELINT 2nd generation

Cosmos 1759	86-47A	Jun 18	PL	C-1	1016	985	82.9	104.9			Military navsat #6
Cosmos 1760	86-48A	Jun 19	TT	A-2	421	218	70.0	90.6	7/3/87	14	Photorecon, R
Molniya 3-29	86-49A	Jun 19	PL	A-2e	415	349	70.0	92.2*			
Cosmos 1761	86-50A	Jul 5	PL	A-2e	40679	640	62.9	736			Communications
Cosmos 1762	86-51A	Jul 10	PL	A-2	39726	630	62.9	717.8*			
Cosmos 1763	86-52A	Jul 16	PL	C-1	39325	607	63	709			Early warning
Cosmos 1764	86-53A	Jul 17	TT	A-2	39747	599	62.9	717.6*			
Cosmos 1765	86-54A	Jul 24	PL	A-2	304	196	82.6	89.2	7/24/86	14	Photorecon/Earth resources (Priroda), R
Cosmos 1766	86-55A	Jul 28	PL	F-2	273	259	82.6	89.9*			
Cosmos 1767	86-56A	Jul 30	TT	J-1	814	761	74.1	100.5			Store-dump communications
Molniya 1-67	86-57A	Jul 30	PL	A-2e	368	182	64.9	89.7	9/11/86	56	Photorecon, D
Cosmos 1768	86-58A	Aug 2	PL	A-2	395	207	72.9	90.2	8/7/86	14	Photorecon, R
Cosmos 1769	86-59A	Aug 4	TT	F-1m	415	356	72.9	92.3*			
Cosmos 1770	86-60A	Aug 6	TT	A-2	679	648	82.5	97.8			Oceanography
Cosmos 1771	86-62A	Aug 20	TT	F-1m	226	198	64.9	88.5	8/16/86	17	Engineering test
Cosmos 1772	86-63A	Aug 21	PL	A-2	40615	658	62.9	736			Communications
Cosmos 1773	86-64A	Aug 27	TT	A-2	39733	620	62.8	717.7*			
Cosmos 1774	86-65A	Aug 28	PL	A-2e	303	199	82.6	89.2	8/16/86	14	Photorecon/Earth resources (Priroda), R
Cosmos 1775	86-66A	Sep 3	TT	A-2	273	259	82.6	89.9*			
Cosmos 1776	86-67A	Sep 3	PL	C-1	456	438	65	93.3	9/21/87	dis	EORSAT
Molniya 1-68	86-68A	Sep 5	PL	A-2e	302	189	64.8	89	2/2/87	180	Photorecon, 5th generation, D
Cosmos 1777	86-70A	Sep 10	PL	C-1	278	254	65	89.6			RORSAT, raised 10/15/86
Cosmos 1778-1780	86-71A-C	Sep 16	TT	D-1e	999	915	65.0	104.2			
Cosmos 1781	86-72A	Sep 17	TT	A-2	370	210	72.9	90	9/3/86	13	Photorecon, R
Cosmos 1782	86-74A	Sep 30	PL	F-2	415	356	72.9	92.3*			
Cosmos 1783	86-75A	Oct 3	PL	A-2e	366	181	64.9	89.7	10/21/86	55	Photorecon, D
Cosmos 1784	86-77A	Oct 6	TT	A-2	39342	614	62.8	709			Early warning
Cosmos 1785	86-78A	Oct 15	PL	A-2e	39723	616	63.0	717.5*			
Molniya 3-30	86-79A	Oct 20	PL	A-2e	405	216	70.3	90.4	9/17/86	14	Photorecon, R
Cosmos 1786	86-80A	Oct 22	TT	J-1	414	348	70.4	92.2*			
Cosmos 1787	86-81A	Oct 22	TT	A-2	521	478	74	94.5			Minor military
Raduga 19	86-82A	Oct 25	TT	D-1e	40558	645	63	735			Communications
Cosmos 1788	86-83A	Oct 27	PL	C-1	39723	630	62.9	717.7*			
Cosmos 1789	86-84A	Oct 31	PL	A-2	819	781	74	100.8			Store-dump communications
						19123	64.8	675			GLONASS, all stabilized
					19144	19116	64.8	675.7*			
					405	217	70.4	90.4	10/1/86	14	Photorecon, R
					416	346	70.4	92.2*			
					677	650	82.5	97.8			
					20045	613	65.8	358			ELINT 2nd generation
							62.8*				Early warning failure
					305	203	64.8	89.3	11/11/86	36	Photorecon, D
					39300	608	62.8	708			Early warning
					39741	595	63.0	717.4*			
					38988	645	62.9	703			Communications
					39724	625	62.9	717.7*			
					2589	198	64.9	113.3			Engineering test
					290	215	70.0	89.3	11/4/86	13	Photorecon, R
					281	230	70.0	89.6*			
						36618	1.3	1479			Geosync communications
					35813	35763	1.3	1436.1*			
					520	472	65.9	94.5			Minor military
					316	196	82.6	89.3	11/14/86	14	Photorecon/Earth resources, R

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
					342	322	82.6	91.2*			
Cosmos 1790	86-85A	Nov 4	PL	A-2	315	207	72.9	89.4	11/18/86	14	Photorecon, R
					282	228	72.9	89.6*			
Cosmos 1791	86-86A	Nov 13	PL	C-1	1026	972	83	105			Civil navsat #11
Cosmos 1792	86-87A	Nov 13	TT	A-2	357	181	64.9	89.6	1/5/87	53	Photorecon, D
Molniya 1-69	86-89A	Nov 15	PL	A-2e	40817	469	62.5	736			Communications
					39898	462	62.9	717.9*			
Gorizont 13	86-90A	Nov 18	TT	D-1e		35824	1.4	1437			Geosync communications
					35796	35769	1.4	1435.8*			
Cosmos 1793	86-91A	Nov 20	PL	A-2e	39323	611	63	709			Early warning
					39750	600	63.0	717.7*			
Cosmos 1794-1801	86-92A-H	Nov 21	PL	C-1	1504	1436	74	115			Tactical Communications, octuple launch
Cosmos 1802	86-93A	Nov 24	PL	C-1	1038	985	83	105			Military navsat #4
Cosmos 1803	86-94A	Dec 2	PL	F-2	1527	1502	82.6	116			Geodesy 2nd generation
Cosmos 1804	86-95A	Dec 4	TT	A-2	448	210	70	90.8	12/18/86	14	Photorecon, R
					415	347	70.0	92.2*			
Cosmos 1805	86-97A	Dec 10	PL	F-2	675	649	82.5	97.8			ELINT 2nd generation
Cosmos 1806	86-98A	Dec 12	PL	A-2e	39307	612	63	708			Early warning
					39730	617	62.9	717.6*			
Cosmos 1807	86-99A	Dec 16	PL	A-2	370	177	67	89.6	1/23/87	38	Photorecon, D
Cosmos 1808	86-100A	Dec 17	PL	C-1	1033	995	83	105			Military navsat #3
Cosmos 1809	86-101A	Dec 18	PL	F-2	980	960	83	104.2			Science, ionospheric research
							82.5*				
Cosmos 1810	86-102A	Dec 26	TT	A-2	203	189	65	89.1	9/11/87	259	Photorecon, 5th generation, D
					265	249	64.8	89.7*			
Molniya 1-70	86-103A	Dec 26	PL	A-2e	39075	484	63	701			Communications
					39876	475	62.8	717.7*			
1987											
Meteor 2-15	87-01A	Jan 5	PL	F-2	973	950	82.5	104			Meteorology
Cosmos 1811	87-02A	Jan 9	TT	A-2	367	181	55	89.7	2/13/87	35	Photorecon, D
					344	172	64.8	89.7*			
Cosmos 1812	87-03A	Jan 14	PL	F-2	677	648	82.5	97.8			ELINT 2nd generation
Cosmos 1813	87-04A	Jan 15	PL	A-2	387	208	72.8	90	1/29/87	dis	Photorecon
					416	356	72.8	92.3*			
Progress 27	87-05A	Jan 16	TT	A-2	280	189	51.6	88.9	2/25/87	40	Freighter to Mir, docked 1/81-2/23/87
Cosmos 1814	87-06A	Jan 21	PL	C-1	815	775	74	100.7			Store-dump communications
Cosmos 1815	87-07A	Jan 22	KY	C-1	558	345	50.7	93.5			Minor military
Molniya 3-31	87-08A	Jan 22	PL	A-2e	40800	473	62.8	736			Communications
					39897	457	62.9	717.8*			
Cosmos 1816	87-09A	Jan 29	PL	C-1	1024	979	82.9	104.9			Civil navsat #14
Cosmos 1817	87-10C	Jan 30	TT	D-1e	224	192	51.6	88.4	3/18/87	47	Geosync communications failure
Cosmos 1818	97-11A	Feb 1	TT	F-1m	810	790	65	100.7			EORSAT 2nd generation
Soyuz-TM 2	87-13A	Feb 5	TT	A-2	308	269	51.6	90.1	7/30/87	174	Manned to Mir, Y Romanenko & A Laveykin, docked 2/7-7/29/87; returned with Viktorenko, Laveykin & Faris [Syria]
Cosmos 1819	87-14A	Feb 7	PL	A-2	254	197	72.8	88.7	2/18/87	11	Photorecon, R
					256	209	72.8	89.2*			
Cosmos 1820	87-16A	Feb 14	TT	J-1	273.2	185.9	64.8	88.8	3/6/87	20	Engineering test
Cosmos 1821	87-17A	Feb 18	PL	C-1	1029	983	82.9	105			Military navsat #5

Cosmos 1822	87-19A	Feb 19	PL	A-2	331.5	205	73	89.5	3/5/87	14	Photorecon, R
					287	228	72.9	89.7*			
Cosmos 1823	87-20A	Feb 20	PL	F-2	1538	1497	73.6	116	12/17/87	dis	Geodesy 2nd generation
Cosmos 1824	87-21A	Feb 26	PL	A-2	370	177	67.2	89.7	4/22/87	55	Photorecon, D
Progress 28	87-23A	Mar 3	TT	A-2	272	191	51.6	88.8	3/28/87	25	Freighter to Mir, docked 3/5-3/26/87
Cosmos 1825	87-24A	Mar 3	PL	F-2	677	649	82.5	97.7			ELINT 2nd generation
Cosmos 1826	87-25A	Mar 11	PL	A-2	403	206	72.9	90.3	3/25/87	14	Photorecon, R
					414	356	72.9	92.3*			
Cosmos 1827-1832	87-26A-F	Mar 13	PL	F-2	1442	1400	82.6	113.9			Sextuple launch
Cosmos 1833	87-27A	Mar 18	TT	J-1	878	851	71	101.9			ELINT 3rd generation
Raduga 20	87-28A	Mar 19	TT	D-1e		35967	1.3	1445			Geosync communications
					35804	35768	1.2	1436.0*			
Kvant	87-30A	Mar 31	TT	D-1	320	177	51.6	89.2			Astronomy module to Mir, docked 4/9
Cosmos 1834	87-31A	Apr 8	TT	F-1m	443	413	65	92.8			EORSAT
Cosmos 1835	87-32A	Apr 9	TT	A-2	367	180	65	89.7	6/4/87	56	Photorecon, D
Cosmos 1836	87-33A	Apr 16	TT	A-2	313	188	65	89.2	12/2/87	230	Photorecon, 5th generation
					293	241	64.8	89.9*			
Progress 29	87-34A	Apr 21	TT	A-2	257	194	51.6	88.7	5/11/87	20	Freighter to Mir, docked 4/23-5/11/87
Cosmos 1837	87-35A	Apr 22	PL	A-2	255	198	82	88.7	4/28/87	6	Photorecon, R
					247	226	82.3	89.3*			
Cosmos 1838-1840	87-36A-C	Apr 24	TT	D-1e	17550	213	64.7	312			GLONASS failure
Cosmos 1841	87-37A	Apr 24	PL	A-2	403	225	62.8	90.5	5/8/87	14	Microgravity materials processing
Cosmos 1842	87-38A	Apr 27	PL	F-2	678	648	82.5	97.8			ELINT 2nd generation
Cosmos 1843	87-39A	May 5	TT	A-2	312	214	70.4	89.5	5/19/87	14	Photorecon, R
					415	347	70.4	92.2*			
Gorizont 14	87-40A	May 11	TT	D-1e		35174	0.52	1401			Geosync communications
					35792	35781	0.9	1436.0*			
Cosmos 1844	87-41A	May 13	TT	J-1	879	861	71	102			ELINT 3rd generation
Cosmos 1845	87-42A	May 13	TT	A-2	400	217	70	90.4	5/27/87	14	Photorecon, R
					415	348	70.4	92.2*			
Energiya		May 15	TT	K-1							Engineering test, payload injection failure
Progress 30	87-44A	May 19	TT	A-2	265	192	51.6	88.8	7/19/87	61	Freighter to Mir, docked 5/21-7/19/87
Cosmos 1846	87-45A	May 21	PL	A-2	314	196	82.4	89.2	6/4/87	14	Photorecon/Earth resources, R
					342	323	82.4	91.2*			
Cosmos 1847	87-46A	May 26	PL	A-2	373	177	67.2	89.7	7/22/87	57	Photorecon, D
Cosmos 1848	87-47A	May 28	PL	A-2	400	208	72.9	90.2	6/11/87	14	Photorecon, R
					414	356	72.9	92.3*			
Cosmos 1849	87-48A	Jun 4	PL	A-2e	39342	613	62.9	709			Early warning
					39728	627	62.9	717.8*			
Cosmos 1850	87-49A	Jun 9	PL	C-1	825	785	74	100.8			Store-dump communications
Cosmos 1851	87-50A	Jun 12	PL	A-2e	39402	582	62.8	710			Early warning
					39743	611	62.9	717.8*			
Cosmos 1852-1859	87-51A-H	Jun 16	PL	C-1	1507	1440	74	115			Tactical communications, octuple launch
Cosmos 1860	87-52A	Jun 18	TT	F-1m	283	255	65	89.7			RORSAT, raised 7/28/87
					953	945	65.0	104.0			
Cosmos 1861	87-54A	Jun 23	PL	C-1	1014	995	83	105			Civil navsat, carries RS10 & RS11 amateur radio
Cosmos 1862	87-55A	Jul 1	PL	F-2	679	645	82.5	97.7			ELINT 2nd generation
Cosmos 1863	87-56A	Jul 4	PL	A-2	383	208	72.9	90.8	7/18/87	14	Photorecon, R
					416	357	72.9	92.3*			
Cosmos 1864	87-57A	Jul 6	PL	C-1	1019	917	83	104.8			Military navsat #5
Cosmos 1865	87-58A	Jul 8	TT	A-2	327	204	64.8	89.5	8/14/87	37	Photorecon, D
Cosmos 1866	87-59A	Jul 9	PL	A-2	386	177	67	89.8	7/26/87	dis	Photorecon, 4th generation
Cosmos 1867	87-60A	Jul 10	TT	F-1m	813	797	65	100.8			EORSAT 2nd generation

Payload name	Designator	Launch date	Site	Launch vehicle	Apogee	Perigee	Inclination	Orbital period	Down	Life	Mission and remarks
Cosmos 1868	87-61A	Jul 14	PL	C-1	726	279	74	94.5			Minor military
Cosmos 1869	87-62A	Jul 16	PL	F-2	679	647	82.5	97.8			Oceanography, radar failed to deploy
Soyuz-TM 3	87-63A	Jul 22	TT	A-2	304	249	51.6	89.9	12/29/87	160	Manned to Mir, A Viktorenko, A Aleksandrov & M Faris [Syria], docked 7/24-12/29/87, transposed 7/29; returned with Romanenko, Aleksandrov & Levchenko
Cosmos 1870	87-64A	Jul 25	TT	D-1	282	168		88.7			Earth resources
					271	254	71.9	89.5			
Cosmos 1871	87-65A	Aug 1	TT	J-1	212	191	97	88.3			Engineering test, retrograde orbit
Progress 31	87-66A	Aug 3	TT	A-2	269	193	51.6	88.8	9/23/87	50	Freighter to Mir, docked 8/5-9/22/87
Meteor 2-16	87-68A	Aug 18	PL	F-2	974	954	82.5	104.1			Meteorology
Cosmos 1872	87-69A	Aug 19	PL	A-2	333	208	72.9	89.6	8/30/87	11	Photorecon, R
					385	247	72.9	90.9*			
Cosmos 1873	87-71A	Aug 28	TT	J-1	274	186	64.8	88.8	9/14/87	18	Engineering test
Cosmos 1874	87-72A	Sep 3	PL	A-2	333	208	73	89.6	9/17/87	14	Photorecon, R
					288	226	72.9	89.7*			
Ekran 16	87-73A	Sep 3	TT	D-1e		35539	0.4	1423			Geosync DBS
					35794	35769	0.4	1435.7*			
Cosmos 1875-1880	87-74A-F	Sep 7	PL	F-2	1437	1401	82.6	114			Sextuple launch
Cosmos 1881	87-76A	Sep 11	TT	A-2	279	190	64.8	89	3/30/88	201	Photorecon, 5th generation
Cosmos 1882	87-77A	Sep 15	PL	A-2	253	196	82.3	88.6	10/6/87	21	Photorecon/Earth resources (Priroda), R, extended duration
					278	256	82.3	89.9*			
Cosmos 1883-1885	87-79A-C	Sep 16	TT	D-1e		19133	64.9	675			GLONASS, all stabilized
					19150	19116	64.9	675.7*			
Cosmos 1886	87-81A	Sep 17	PL	A-2	384	178	67.2	89.8	11/2/87	46	Photorecon, D
Progress 32	87-82A	Sep 23	TT	A-2	267	193	51.6	88.8	11/19/87	56	Freighter to Mir, docked 9/26-11/10, re-docked 11/10-11/17/87
Cosmos 1887	87-83A	Sep 29	PL	A-2	384	224	62.8	90.5	10/12/87	13	Biosatellite
Cosmos 1888	87-84A	Oct 1	TT	D-1e		35980	1.4	1443			Geosync communications
					35805	35765	1.4	1435.9*			
Cosmos 1889	87-85A	Oct 9	TT	A-2	400	216	70	90.4	10/23/87	14	Photorecon, R
					415	348	70.0	92.2*			
Cosmos 1890	87-86A	Oct 10	TT	F-1m	442	414	65	92.9			EORSAT
					417	403	65.0	92.8*			
Cosmos 1891	87-87A	Oct 14	PL	C-1	1030	957	83	104.9			Military navsat #6
Cosmos 1892	87-88A	Oct 20	PL	F-2	678	647	82.5	97.8			ELINT 2nd generation
Cosmos 1893	87-89A	Oct 22	PL	A-2	374	179	67	89.7	12/16/87	55	Photorecon, D
Cosmos 1894	87-91A	Oct 28	TT	D-1e		35920	1.3	1442			Geosync communications
					35794	35778	1.1	1436.0*			
Cosmos 1895	87-92A	Nov 11	TT	A-2	402	217	70.4	09.4	11/26/87	15	Photorecon, R
					288	228	70.4	89.7*			
Cosmos 1896	87-93A	Nov 14	TT	A-2	319	203	64.8	89.4	12/25/87	41	Photorecon, D
Progress 33	87-94A	Nov 20	TT	A-2	268	193	51.6	88.8	12/19/87	29	Freighter to Mir, docked 11/22-12/19/87
Cosmos 1897	87-96A	Nov 26	TT	D-1e		35770	1.4	1435			Geosync data-relay
					35825	35745	1.3	1435.9*			
Cosmos 1898	87-98A	Dec 1	PL	C-1	820	781	74	100.8			Store-dump communications
Cosmos 1899	87-99A	Dec 7	TT	A-2	297	216	70.4	89.3	12/21/87	14	Photorecon, R
Raduga 21	87-100A	Dec 10	TT	D-1e		35000	1.3	1396			Geosync communications
					35799	35779	1.3	1436.1*			
Cosmos 1900	87-101A	Dec 12	TT	F-1m	287	263	65	89.8			RORSAT 2nd generation
Cosmos 1901	87-102A	Dec 14	TT	A-2	376	181	65	89.8	2/3/88	51	Photorecon

Cosmos 1902	87-103A	Dec 15	PL	C-1	417	373	66	92.4			Minor military
							65.8*				
Soyuz-TM 4	87-104A	Dec 21	TT	A-2	298	260	51.6	89.9			Manned to Mir, V Titov, M Manarov & A Levchenko, docked 12/23/87, transposed 12/30/87
Cosmos 1903	87-105A	Dec 21	PL	A-2e	39342	614	62.8	709			Early warning
					39757	588	63.0	717.6*			
Cosmos 1904	87-106A	Dec 23	PL	C-1	1021	989	83	104.9			Military navsat #2
Cosmos 1905	87-107A	Dec 25	TT	A-2	298	216	70.4	89.3	1/8/88	14	Photorecon, R
Cosmos 1906	87-108A	Dec 26	PL	A-2	274	190	82.6	88.8	1/31/88	dis	Photorecon/Earth resources 2nd generation
					277	257	82.6	89.9*			
Ekran 17	87-109A	Dec 27	TT	D-1e		35628	1.5	1428			Geosync DBS
					35851	35720	1.6	1435.9*			
Cosmos 1907	87-110A	Dec 29	PL	A-2	398	208	72.9	90.2	1/12/88	14	Photorecon, R
					415	356	72.8	92.3*			

[1] Similar parameters.